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Analysis of the Sustainment Organization and Process for the Marine Corps RQ-11B Raven Small Unmanned Aircraft System (SUAS)

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Analysis of the Sustainment Organization and Process for the Marine Corps' RQ-11B Raven Small Unmanned Aircraft System (SUAS)

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March 2012

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This report serves as a case study for insights into the acquisition strategies for future unmanned systems. I explore the advantages and limitations of organic versus contractor support options in the form of monetary, organizational, and logistical resource allocation by analyzing the spectrum of solutions throughout the supply and maintenance constructs. The analysis covers both operational and sustainment perspectives through the lens of doctrine, organization, training, material, leadership and education, personnel, and facilities implications.

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ANALYSIS OF THE SUSTAINMENT ORGANIZATION AND PROCESS FOR THE MARINE CORPS' RQ-11B RAVEN SMALL UNMANNED AIRCRAFT SYSTEM (SUAS)

Jeffery Van Bourgondien, Captain, United States Marine Corps

Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

The purpose of this study is to outline and analyze the acquisition and sustainment process for the current U.S. Marine Corps' RQ-11B Raven Digital Data Link small unmanned aerial system program. The current sustainment of the Marine Corps' Raven evolved from the support employed for its predecessor analog variant in 2008, which was originally supported by Marine organic assets below depot-level maintenance requirements. The Raven's manufacturer, AeroVironment Inc., now stations a field service representative in theater and has been since around June 2011 under a contractor logistics support contract after the Marine Corps struggled to implement organic support and sustain its Ravens at the organizational and intermediate levels.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Abbreviated Acquisition Program
ACE	Aviation Combat Element
AE	All Environment
AROD	Airborne Remotely Operated Device
AV	AeroVironment Inc.
BCA	Business Case Analysis
BLOS	Beyond Line-of-Sight
C-MNS	Combat Mission Need Statement
C2	Command and Control
CAIV	Cost as an Independent Variable
CCB	Configuration Control Board
CDD	Combat Capabilities Directorate
CG	Commanding General
CLIC	Company-Level Intelligence Cells
CLS	Contractor Logistics Support
CMC	Commandant of the Marine Corps
CONOPS	Concept of Operations
COTS	Commercial Off-the-Shelf
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DARPA	DoD Advanced Research Projects Agency
CD&I	Combat Development and Integration
DDL	Digital Data Link

DE	Dragon Eye
DoD	Department of Defense
ECP	Engineering Change Proposal
EFDS	Expeditionary Force Development System
EUA	Extended User Assessment
FEBA	Forward Edge of the Battle Area
FONS	Fleet Marine Force Operational Need Statement
FOB	Forward Operating Base
FoS	Family of Systems
FRK	Field Repair Kit
FRP	Full-Rate Production
FSR	Field Service Representative
GATERS	Ground/Air Tele-robotics Systems
GCS	Ground Control Station
GCE	Ground Combat Element
GPS	Global Positioning System
HMMWV	Highly Mobile Multi-wheeled Vehicle
IOC	Initial Operational Capacity
I-SURSS	Interim Small Unit Remote Scouting System
IPT	Integrated Product Team
ISP	Initial Spares Package
ISR	Intelligence, Surveillance, and Reconnaissance
JPO	Joint Program Office
KPP	Key Performance Parameter
LCCE	Lifecycle Cost Estimate

LCE	Logistics Combat Element
LOE	Limited Objective Experiment
LRIP	Low-Rate Initial Production
MAGTF	Marine Air-Ground Task Force
MAV	Micro Air Vehicle
MCCDC	Marine Corps Combat Development Command
MC2I	Weapons & Sensors Development & Integration
MCSC	Marine Corps Systems Command
MCWL	Marine Corps Warfighting Laboratory
MDA	Milestone Decision Authority
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
MITE	Micro Tactical Expendable
MOA	Memorandum of Agreement
MOOTW	Military Operations Other Than War
MOS	Military Occupation Specialty
MROC	Marine Requirements Oversight Council
MUAV	Micro Unmanned Aerial Vehicle
NAS	Naval Air Station
NAVAIR	Naval Air Systems Command
NOSC	Naval Ocean Systems Center
NRaD	Naval Research and Development
NRL	Naval Research Laboratory
O&M	Operations and Maintenance
O&S	Operating and Support

OEF	Operation Enduring Freedom
OEM	Original Equipment Manufacturer
OIF	Operation Iraqi Freedom
ORD	Operational Requirements Document
OTH	Over the Hill
PEO(U&W)	Program Executive Office for Unmanned Aviation and Strike Weapons
PG-11	Product Group 11
PM	Program Manager
PM-UAS	Program Manager for Unmanned Aviation Systems (U.S. Army)
PO	Project Office
PoR	Program of Record
R&D	Research and Development
RCT	Regimental Combat Team
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RPV	Remotely Piloted Vehicle
RVT	Remote Video Terminal
SEP	Service Extension Program
SOW	Statement of Work
SPAWAR	Space and Naval Warfare Systems Command
SUAS	Small Unmanned Aerial System
TOC	Total Ownership Costs
TOE/TO&E	Table of Organization and Equipment
TOV	Tele-operated Vehicle
UAS	Unmanned Aircraft System
UCAV	Unmanned Combat Air Vehicles

UNS	Universal Needs Statement
USMC	United States Marine Corps
VLC	Very Low-Cost
VMU	Unmanned Aerial Vehicle Squadron
VTOL	Vertical Takeoff and Landing

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I. INTRODUCTION

The RQ-11B Raven with digital data link (DDL) is the U.S. Marine Corps' (USMC) latest program of record (PoR) providing an intelligence, surveillance, and reconnaissance (ISR) unmanned aircraft system (UAS) solution for the lowest command echelon of the Marine Air-Ground Task Force (MAGTF). It is procured through the Naval Air Systems Command (NAVAIR) in concert with (and under a prime contract via) the U.S. Army's program manager for UASs (PM-UAS). Intended as a battalion-level asset, the Raven B (an analog variant) has been employed by the Marines during combat operations in both Iraq and Afghanistan since 2008. It replaced the RQ-14A Dragon Eye UAS, the Corps' first hand-launched reconnaissance mini-UAV. The Raven has a history of being hugely successful on the battlefield by providing real-time aerial intelligence for Marines and soldiers on the front lines.

A. PURPOSE

The purpose of this study is to outline and analyze the acquisition and sustainment process for the current U.S. Marine Corps' (USMC) RQ-11B Raven small unmanned aerial system (SUAS) program. It serves as a case study for insights into the acquisition strategies for future unmanned systems. Additionally, in this business case analysis (BCA) I identify potential costs and benefits of an original equipment manufacturer (OEM) contractor logistics support (CLS) contract for Raven's supply and maintenance services. I explore the advantages and limitations of this option in the form of monetary, organizational, and logistical resource allocation by analyzing the spectrum of solutions the Marine Corps and Naval Air Systems Commands (NAVAIR) used within the OEM-CLS blended sustainment model. The main objectives of this thesis are to accomplish the following:

- document the Marine Corps Raven SUAS sustainment process and organization;
- research and record lessons learned;

- assess the performance for the sustainment of the past and current programs;
- determine what benefits the Marine Corps realized through the current OEM-CLS contract; and
- develop heuristics and/or criteria to help improve Marine Corps UAS acquisition and sustainment processes.

B. PROBLEM STATEMENT

The Raven B DDL (Digital Data Link) is currently being fielded to Marines in Afghanistan and supported through a modified OEM logistics contract for parts and maintenance. The current sustainment of the Marine Corps' Raven DDL evolved from the support employed for its predecessor variants, which were originally supported by Marine organic assets below depot-level maintenance requirements. According to a logistics analyst at the NAVAIR, an AeroVironment Inc. (AV) field service representative (FSR) is now stationed in theater and has been since around June 2011 in order to provide the most responsive support possible. This representative is available in addition to AV's CONUS locations. The decision to contract logistics support came after NAVAIR and the Marine Corps unsuccessfully attempted to implement organic support at the intermediate and depot level of maintenance and supply. However, there is little analytical evidence to indicate whether an OEM sustainment contract was the best decision.

C. RESEARCH OVERVIEW

1. Research Objectives

In this research I analyze the benefits and limitations of an OEM-CLS sustainment model for the life cycle of the Raven UAS. First, I analyze the supply and maintenance concepts from both operational and sustainment perspectives through the lens of doctrine, organization, training, material, leadership and education, personnel, and facilities (DOTMLPF) implications. While cost is both an easy and important metric to analyze, it is only a single element the program office must weigh when determining the

best value sustainment model. I explore the benefits and limitations of each aspect of the sustainment design in this research. This portion of the analysis is qualitative rather than quantitative and is based upon expert accounts from the UAS development, sustainment, and user communities that support and employ the Marine Corps' Raven.

Secondly, I analyze the costs for the Raven B procurement decision as well as the organic/CLS blended model of sustainment. I compare the construct at the beginning of the Marine Corps' Raven program in 2008 with the current costs of the 2011 modified organic/CLS blended sustainment model. The cost analysis will include an evaluation of whether the decision to implement OEM-CLS with AV has translated into either significant monetary or other savings for the Marine Corps.

2. Analysis Questions

- What are the operational and logistical impacts of using a hybrid organic/CLS solution for supply and maintenance support of the RQ-11B Raven?
- Is the increased cost of the modified CLS contract supporting the RQ-11B Raven worth the supply and maintenance benefits?

D. SCOPE AND METHODOLOGY

Analysis of the data comes from an examination of the organization of UAS-equipped and supporting units along with associated logistics agencies within the USMC. The information provides insights on how the Marines support the Raven through supply chain management and maintenance procedures in consonance with the OEM. This study conducts a business case analysis (BCA) comparing the sustainment costs of the current Marine Corps ISR Raven DDL program with the sustainment costs of the original Raven analog variant. The results of this study help set benchmark guidelines for future UAS acquisitions and their associated sustainment strategies.

E. ORGANIZATION

I present a broad overview of this report and lay out the general roadmap of the research in Chapter I, through a purpose, problem statement, research questions, methodology, organization, and benefits of this study.

In Chapter II, I provide an overview of both the DoD and USMC initial involvement with the development, procurement, and employment of some of America's first military unmanned aerial systems. I also outline some of the trends in global, national, and DoD priorities to support the rising development and use of unmanned technologies and provide supporting evidence from spending analysis and system inventories.

In Chapter III, I present the case study of the RQ-11B Raven DDL beginning with an introductory history of the weapon system and the SUAS program starting with its technological predecessors, its mission, and its technical capabilities.

In Chapter IV, I provide a summary of the evolution in sustainment methodologies and details on Raven's operational, maintenance, and support structures using the DOTMLPF analysis method, including lessons learned from the operating forces and supporting establishments. I also provide a look at Raven's original programmed sustainment strategy and an analysis of the major costs and current operational sustainment constructs. In this chapter I include a description of this case study that can be applied to future Marine Corps acquisition and sustainment endeavors.

In Chapter V, I answer the research questions I propose in Chapter I, summarize the findings of the research, and present recommendations for further research and study.

F. BENEFITS OF STUDY

I expect that this analysis will aid the USMC and NAVAIR to make improved UAS acquisition and sustainment strategies.

II. BACKGROUND

Experience in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) has proven that UASs are invaluable to American warfighters. In particular, UASs designed for reconnaissance, intelligence, surveillance, and target acquisition (RSTA), have proven to be relatively low-cost assets used for acquiring tactical intelligence. These systems have been in regular use since the early 1990s and range in size and sophistication from very small systems that can be launched by hand for short-range operations to high-altitude systems that can acquire much of the same information as reconnaissance satellites (Best, 2011, p. 2).

A. SHORT HISTORY: DOD UNMANNED AERIAL SYSTEMS

Although the first documented use of unmanned aircraft was for attack during the American Civil War, the U.S. has only seriously experimented with unmanned aerial systems since World War I. However, only after World War II did the DoD effectively develop or use UASs in training and combat, such as the AQM-34 Firebee in Southeast Asia. The AQM-34s were originally developed in the 1950s as aerial target drones; however, they were later adapted for use as intelligence-gathering assets during the Vietnam War (Gertler, 2012, p. 1).

Its use was limited compared to manned aircraft conducting similar missions at the time, and although successful, it did not initiate the current proliferation of UASs across the globe. There was an American resurgence of interest in the 1980s, especially when Israel experienced great success using unmanned systems in Lebanon in 1982. In addition, fundamental developments revived interest globally. One change was the reduced cost of unmanned technologies and advent of cheaper innovations (i.e., using the derivative of radio-controlled model aircraft). This shift toward using smaller, lower-cost systems also had the advantages of reduced weight, volume, power consumption, and inexpensive modular electronic components (Sweetman, 1985).

However, the American use of tactical unmanned assets gained increased acceptance during Operations Desert Shield and Desert Storm in 1990–1991 for their operational utility and relatively low cost. The well-publicized incident in which a troop of Iraqi soldiers apparently surrendered to a UAS, also helped (Nader, 2007, p. 7).

The advantages of using UASs in ever-increasing ranges and numbers of operations are continually revealed, documented, and analyzed. Examples of success range from missions in combat to military operations other than war (MOOTW) throughout the world; these include battle damage assessments over Kosovo in 1999, aerial pictures to assist with relief efforts in the wake of the 2010 earthquake in Haiti, and, most especially, in combat throughout the enduring Global War on Terror (GWOT) since 2001 (Gertler, 2012, p. i).

Today, with U.S. UAS inventory reaching nearly 7,500, there are hundreds of configurations and unique platforms of UASs in service for military, civilian, and commercial use worldwide. This does not include ground-based platforms, maritime systems, or those in development (Gertler, 2012, p. 8). The size, aeronautical design, and mission of these systems vary greatly from very small to extremely large, from rotary-wing to fixed-wing, and from aerial reconnaissance to delivering lethal precision-guided munitions. The U.S. military is by far the heaviest user, levying the largest demand on American manufacturers, who possess over 64% of the total world market share. The remaining share belongs to Israeli companies (4%), European companies (3%), other companies (14%), and unawarded contracts (15%; Fulghum, 2012, p. 70). The growing UAS market involved purchases of over $42 billion for research and development (R&D) and production in 2011 (Fulghum, 2012, p. 68).

In order to keep up with increasing operational demand, the DoD spends billions of American defense dollars annually on researching, developing, procuring and sustaining these systems. According to the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) in the 2011 DoD UAS roadmap, the number of hours flown by American UAS platforms (depicted in Figure 1) has increased by nearly 600% from 1996 to 2009 and does not include small aircraft such as the Raven.

Just a year later in November 2010, the Army reported over 1 million UAS combat flight hours, including small unmanned aircraft.

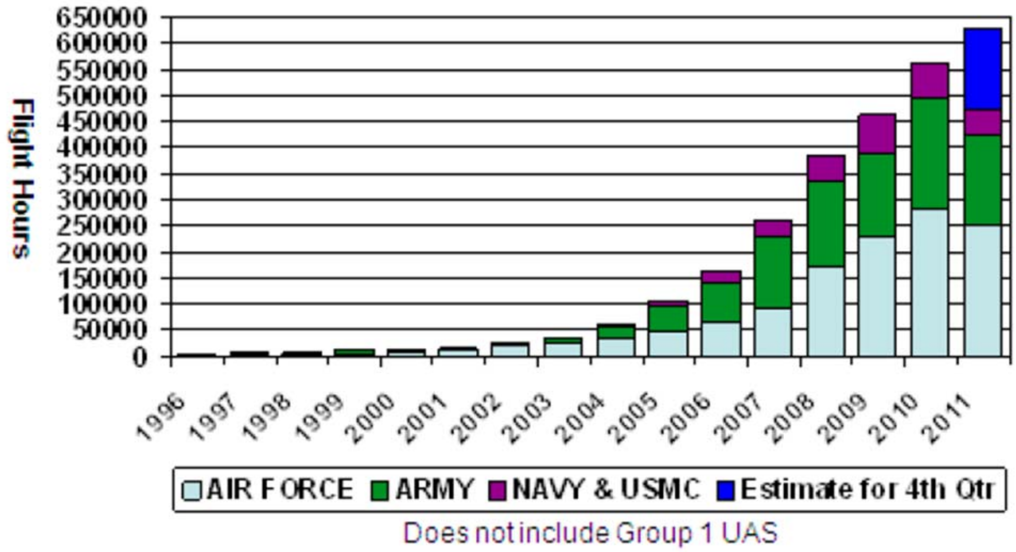
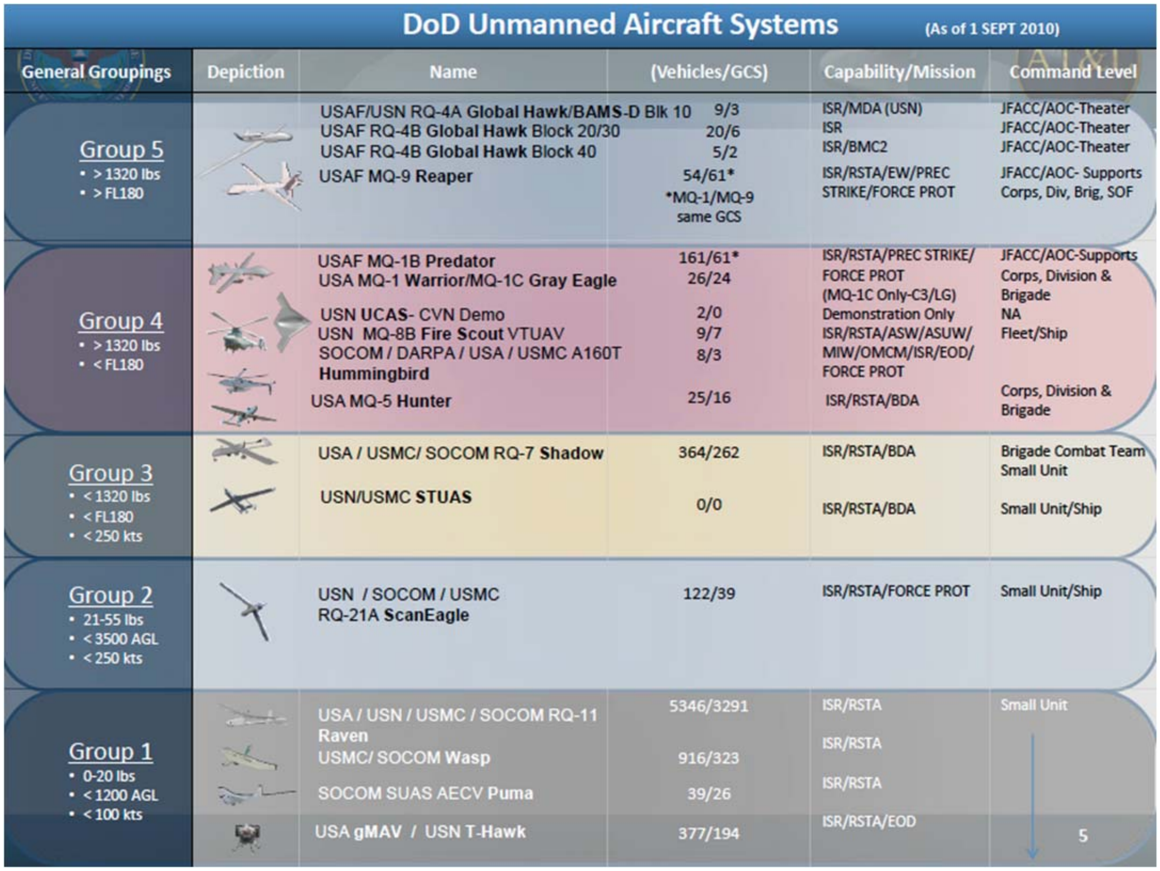


Figure 1. UAS Flight Hours, 1996–Present (From: USD[AT&L], 2011)

The current inventory of U.S. unmanned aerial systems is 10 times greater than it was 20 years ago (Fulghum, 2012). The U.S. President's 2011 budget included over $6 billion for R&D, procurement, and operations and maintenance (O&M) for aerial systems alone, which is more than double what it was in 2005. The President's projected budgets for 2012 through 2015 feature nearly identical sums (Gertler, 2012). The overall focus on the acquisitions of unmanned systems has been trending unrelentingly upward since the 1990s, only declining slightly with the decrease in combat operations in Iraq over the last two years.

In an effort to better manage its rapidly expanding UAS force, the DoD organized its systems into various categories. Formerly called *tiers*, the different types of UASs are now classified by *groups*, distinguished by size, weight, and flight endurance as shown in Figure 2. Group 5 includes the largest UASs of these categories, those systems with the greatest endurance and weights in excess of 1320 pounds. The next echelon is Group 4, which includes UASs with similar weight characteristics as Group 5 but with flight endurances less than 180 hours.



DoD Unmanned Aircraft Systems (As of 1 SEPT 2010)

General Groupings	Depiction	Name	(Vehicles/GCS)	Capability/Mission	Command Level
Group 5 • > 1320 lbs • > FL180		USAF/USN RQ-4A Global Hawk/BAMS-D Blk 10 USAF RQ-4B Global Hawk Block 20/30 USAF RQ-4B Global Hawk Block 40 USAF MQ-9 Reaper	9/3 20/6 5/2 54/61* *MQ-1/MQ-9 same GCS	ISR/MDA (USN) ISR ISR/BMC2 ISR/RSTA/EW/PREC STRIKE/FORCE PROT	JFACC/AOC-Theater JFACC/AOC-Theater JFACC/AOC-Theater JFACC/AOC- Supports Corps, Div, Brig, SOF
Group 4 • > 1320 lbs • < FL180		USAF MQ-1B Predator USA MQ-1 Warrior/MQ-1C Gray Eagle USN UCAS- CVN Demo USN MQ-8B Fire Scout VTUAV SOCOM / DARPA / USA / USMC A160T Hummingbird USA MQ-5 Hunter	161/61* 26/24 2/0 9/7 8/3 25/16	ISR/RSTA/PREC STRIKE/ FORCE PROT (MQ-1C Only-C3/LG) Demonstration Only ISR/RSTA/ASW/ASUW/ MIW/OMCM/ISR/EOD/ FORCE PROT ISR/RSTA/BDA	JFACC/AOC-Supports Corps, Division & Brigade NA Fleet/Ship Corps, Division & Brigade
Group 3 • < 1320 lbs • < FL180 • < 250 kts		USA / USMC/ SOCOM RQ-7 Shadow USN/USMC STUAS	364/262 0/0	ISR/RSTA/BDA ISR/RSTA/BDA	Brigade Combat Team Small Unit Small Unit/Ship
Group 2 • 21-55 lbs • < 3500 AGL • < 250 kts		USN / SOCOM / USMC RQ-21A ScanEagle	122/39	ISR/RSTA/FORCE PROT	Small Unit/Ship
Group 1 • 0-20 lbs • < 1200 AGL • < 100 kts		USA / USN / USMC / SOCOM RQ-11 Raven USMC/ SOCOM Wasp SOCOM SUAS AECV Puma USA gMAV / USN T-Hawk	5346/3291 916/323 39/26 377/194	ISR/RSTA ISR/RSTA ISR/RSTA ISR/RSTA/EOD	Small Unit

5

Figure 2. DoD Unmanned Aircraft Capabilities by Program (From: USD[AT&L], 2011)

Group 2 encompasses medium-range small tactical UAS (STAUS), to which battlefield commanders have even greater access. They weigh between 21 and 55 pounds, fly no higher than 3500 feet above ground level (AGL), and fly only as fast and as long as the systems in Group 3.

Finally, Group 1 incorporates the small platforms (SUAS; less than 20 pounds), which have a shorter on-station time than their larger counterparts. Group 1 possesses the greatest number of systems than all the other groups combined, comprising 90% of all systems in the DoD's inventory (Gertler, 2012). However, sometimes both inadequate leadership visibility and resources dedicated to managing and sustaining these systems cause issues with the acquisition and effective sustainment of this important subset of UASs.

The range of missions and capabilities assigned to unmanned aircraft is expanding as these systems are projected, with few exceptions, to assume nearly every manned aircraft mission in the future. Nearly all current UASs are exclusively developed for RSTA or ISR with communication relay capability. However, "weaponizing" intelligence-gathering UASs with precision-guided munitions for strike missions is becoming more commonplace. Now a new category of UAS is in development specifically designed for direct combat action. Unmanned combat air vehicles (UCAVs) will have greater speed, payload capacity, and stealth than current ISR models, with attack/strike missions as their primary tasking.

Other potential roles of UASs are expected to materialize in the not-too-distant future. These additional roles include electronic warfare, air-to-air combat, search and rescue, aerial refueling, and cargo resupply. Among new roles for UASs is the Navy and Marine Corps' effort to develop and employ a UAS capable of cargo resupply either at sea or on land. A commercially-developed rotary-wing UAS is currently in Afghanistan undergoing user evaluations.

B. U.S. MARINE CORPS UNMANNED AERIAL SYSTEM OVERVIEW

The Marine Corps continues to refine its UAS concept of operations (CONOPS) a half century after it started experimenting with unmanned aerial vehicles (UAVs) in the 1960s. UAV technological and employment concepts started in the 1950s when the Marines, in collaboration with the U.S. Navy, developed the XRON-1 Rotorcycle in which the Gyrodyne Company of America produced. The XRON-1 was a manned mini-helicopter conceptually intended to provide an escape vehicle for downed pilots in treacherous or otherwise un-navigable enemy territory (Gyrodyne Helicopter Historical Foundation [GHHF], 1999). Although the XRON was never adopted, the Navy continued to collaborate with Gyrodyne in 1958 to develop an unmanned technical byproduct of the mini-helicopter called the QH-50 Drone Anti-Submarine Helicopter (DASH). The Navy intended to use the DASH to remotely deliver depth charges.

In 1968, the DoD's Advanced Research Projects Agency (DARPA), and Gyrodyne commenced the modification of the QH-50D, as shown in Figure 3, under the

Nite Panther Program concept in response to an urgent Marine operational requirement. The Marines' employment concept was to launch it from ships steaming near enemy littorals, fly it to targeted beachheads, and use it to conduct reconnaissance before troops debarked for their amphibious landing. The system had a daylight TV camera, a nighttime TV camera, a still photographic camera, and a laser rangefinder, supported by a control station mounted on a truck equipped with the target control system. Successfully tested and adopted, the three systems procured were sequentially lost in three days' time after launching into Vietnam in April 1968. The technology developed from the Nite Panther remotely piloted vehicle (RPV) was used in other programs; however, the Marine Corps did not integrate unmanned systems in its operations again until the mid-1980s (GHHF, 1999).

Figure 3. The Nite Panther RPV and Control Station—1968 (From: GHHF, 1999)

The Corps established its first RPV platoon at Camp Lejeune in 1984, incorporating unmanned vehicles in its table of organization and equipment (TO&E) for the first time. The 42-man platoon's mission was assisting in acquiring targets for artillery and naval gunfire as well as adjusting fires. The unit was issued four Mastiff-3 mini-RPVs, with which the Marines both trained and conducted testing trials, but never used in real-world operations.

The Mastiff-3, designed and manufactured by the Israeli company Tadiran Electronic Systems, was controlled by five Marines, had a gross weight over 250 pounds, a range of 100 kilometers, and had a flight endurance of nearly seven hours (USMC History Division, 1984). Although the Mastiff-3 was the first relatively small short-range unmanned aerial vehicle in the Marines' inventory, the Corps first operationally used unmanned systems in 1986 when the Navy selected the RQ-2 Pioneer as its standard short-range RPV.

The Pioneer, technically a derivative of both the Israeli Scout and Mastiff RPVs, was built in the U.S. by AAI Corporation. The system weighed over 400 pounds and was launched by rocket assist (shipboard), by catapult, or from a runway. The Marines employed the Pioneer and its upgraded variants from 1986 through about 2007 when it was replaced with the Group 3 Shadow UAS.

At the same time the Navy and Marine Corps acquired the Pioneer UAV in 1986, AV designed a smaller battlefield UAV called the FQM-151 Pointer UAV. The Pointer was significantly smaller than the Pioneer, weighing only 10 pounds, and served the Marines as its first man-portable, hand-launched system for infantrymen to see beyond line of sight (BLOS). The Pointer provided color and infrared (IR) video from front or side views, operated with a global positioning system (GPS) to auto-navigate, executed man-in-the-loop control, and remained recoverable in obstructed areas. The logistical footprint for the Pointer was drastically smaller than any other unmanned system the Marines had used before, and it was critical to units needing immediate intelligence on the battlefield and essentially serves as the model for small fixed-wing UASs to this day (Munson, 2000). The Pointer served the Marine Corps from 1990 until it was replaced by the Group 1-equivalent RQ-14 Dragon Eye in 2003.

The Naval Research Laboratory (NRL) developed the Dragon Eye in 2000 for the Marines. AV was selected to optimize the design for enhanced manufacturability and reliability, and the system first flew in 2001. After testing and user trials, the Dragon Eye reached initial operational capability (IOC) in 2003 when the Marines deployed it in support of Operation Iraqi Freedom. The system was smaller, weighing about five pounds, and served as the Corps' smallest tactical reconnaissance and surveillance UAS

yet. The Dragon Eye fulfilled the Navy's Over-The-Hill (OTH) reconnaissance initiative and the Marines' Interim Small Unit Remote Scouting System (I-SURSS) requirement, although other micro and small UAVs were in development as well. The Dragon Eye, however, was soon afterwards targeted for replacement in 2006. The Marine Corps decided to transition to the current USMC acquisition program of record fielding the organic battlefield SUAS—the RQ-11 Pathfinder Raven, which started its changeover in the field in 2008.

Among all the programs managed by the Navy and Marine Corps unmanned systems project office, the Raven is the workhorse; it has the most total systems in the Services' entire UAS inventory at 425 fielded systems. Each Raven system contains three individual air vehicles, totaling 1275 aircraft fielded—three times as many as the next most numerous UAS in the Navy's Group 1 inventory (Wasp; NAVAIR, 2012). The DoD owns over 5300 RQ-11 air vehicles in service with the Marines, Air Force, Army, and Special Operation Command (SOCOM). The Wasp also comes in a distant second to the Raven at a little over 900 systems in the total DoD inventory (Gertler, 2012). Although the Raven does not compare in capability to the larger, more sophisticated UASs like the Global Hawk, Reaper, or Predator, the sheer number of systems and resources dedicated to managing the system requires a high level of attentiveness to deal with support strategies at any level of the DoD.

C. USMC UNMANNED AERIAL SYSTEM ORGANIZATION

Since 2001, the demand for dedicated aerial reconnaissance assets has grown rapidly during the course of the War on Terror. In concert with the DoD, the Marine Corps has continually refined its UAS requirements and CONOPS and documented them in its vision for a UAS family of systems (FoS). The Corps has evolved, developed, and executed its procurement and fielding strategies for improved unmanned systems at every level of the MAGTF. Today, the Marine Corps UAS CONOPS divides its unmanned systems requirement into three levels that coincide with the various echelons of command in the MAGTF. The smaller, but more numerous systems (Group 1), directly support lower tactical units such as company- and battalion-sized elements, whereas the larger

systems (Groups 2 and 3) support higher levels of command such as the Marine Expeditionary Unit (MEU) or Regimental Combat Team (RCT; MCCDC, 2009).

All USMC Group 1 systems are considered organic assets to battalion-sized units and smaller; they are typically owned and operated with limited maintenance by Marine infantrymen engaged in combat operations. Although the Raven is the Marines' only official SUAS PoR today, the Group 1 program office at NAVAIR manages numerous program initiatives responding to relatively recent urgent needs statements. These other systems do not typically appear by name in high-level DoD or Navy and Marine Corps budget/funding profiles; however, they are part of the SUAS program and may eventually become standalone PoRs. Those systems include the AV-produced Puma AE (All Environment) UAS (a fixed-wing sister platform to the Raven with greater capability); Honeywell's RQ-16B T-Hawk vertical takeoff and landing (VTOL) Micro Air Vehicle (MAV); and the AV-manufactured Wasp micro unmanned aerial vehicle (MUAV). The two latter platforms have been in regular use by Marines since around 2008 and 2009 respectively (NAVAIR, 2012).

The larger unmanned systems in Groups 2 and 3 are organic to Marine Unmanned Aerial Vehicle Squadrons (VMUs). VMUs are a reorganized and re-designated form of the previously known RPV platoons, fulfilling a similar role of non-organic aerial intelligence support to battalion-size and larger units. VMUs are subordinate to the MAGTF Air Wing and are either task-organized and attached to the headquarters of expeditionary units or deployed as a squadron in general intelligence support. The difference between organic UASs and VMU assets is that the image output from VMUs must be pushed or requested through designated intelligence channels (MCCDC, 2009).

Today's inventory of Marine Corps UASs in Groups 2 and 3 include larger, more capable ISR assets. The Group 2 STUAS platform for the Navy and the Marines is Scan Eagle, a system built by Institu Inc., a subsidiary of the Boeing Company. Although the operation and support of Scan Eagle is currently contracted through Boeing, the system is considered an organic asset to VMU since its introduction in 2008. Fulfilling the Group 3 tactical UAS (TUAS) role is the previously mentioned RQ-7 Shadow, designed and manufactured by AAI Corp. (NAVAIR, 2012).

One future UAS capability currently under NAVAIR's assessment is an air platform called the RQ-21 Integrator; it is also built by the Institu/Boeing team and has greater avionic and sensor capability than its predecessors. The Integrator is intended for maritime and ground ISR/RSTA as a Group 3 system, which will replace both the Group 2 Scan Eagle and Group 3 Shadow, starting around the fourth quarter of 2013 (NAVAIR, 2012).

The Marine Corps is also acquiring a commercial off-the-shelf (COTS) rotary-wing unmanned helicopter for unmanned aerial cargo resupply. Lockheed Martin's KMAX beat out Boeing's Hummingbird in a down-select competition and is now accumulating data in active mission testing and user evaluations in Afghanistan to identify its future operational and sustainment impacts (Peterson & Staley, 2011). Although the Marines and the Navy are leading the acquisition efforts for the cargo system, all Services are awaiting their opportunity to procure the newest unpiloted resupply capability. The DoD will categorize the Cargo UAS in its Group 4 of unmanned systems.

D. ACQUSITIONS PROCESS AND PROGRAM MANAGEMENT

Unlike most acquisitions processes in the DoD, the Navy and Marine Corps have a unique relationship that leads to unique UAS acquisition processes. While the Air Force and Army manage their acquisition processes for the research and procurement of all their aircraft, the Marines rely on the Navy's program management offices at NAVAIR. The NAVAIR and the Marine Corps' principal development and acquisitions agencies are tied together with a series of operating agreements. The Marine Corps begins its acquisitions process by brainstorming and conceptualizing solutions in response to needs statements or perceived capability gaps. The Marine Corps uses the Expeditionary Force Development System (EFDS), denoted in Figure 4, which is a four-phased process that is synchronized with the Planning, Programming, Budgeting, and Execution System (PPBES) and the Defense Acquisition System (DAS).

It is a coordinated effort, led and managed by the Deputy Commandant for Combat Development and Integration, Headquarters Marine Corps (CD&I), who also acts as the commanding general (CG) of the Marine Corps Combat Development Command (MCCDC; MCCDC, 2008).

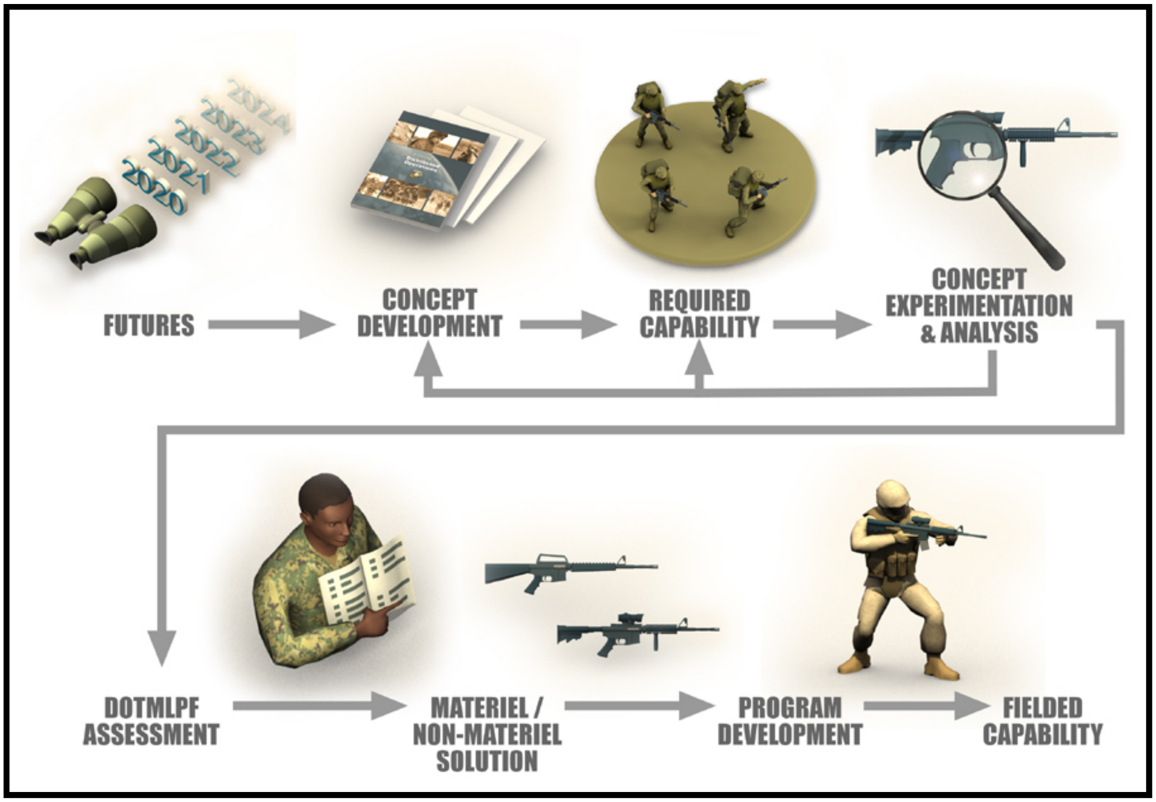


Figure 4. The Marine Corps Expeditionary Force Development System (From: MCCDC, 2008)

Subordinate to CD&I/MCCDC are its working groups, the Combat Capabilities Directorate (CDD) and the Marine Corps Warfighting Lab (MCWL). The CDD is the custodian of the EFDS and analyzes and develops solutions for the Marine Forces (MARFORs). CDD coordinates with Marine Corps advocates, proponents, MARFORs, and supporting establishment to ensure that the fielding of warfighting capabilities is integrated across the DOTMLPF solution framework. The MCWL is a combination think tank and laboratory. The Warfighting Lab analyzes and tests new and emerging concepts from today's industry and individual Marines to determine if they would

function in combat and if they are a solution for a current problem (MCCDC, 2008). The CDD and MCWL collaboratively decide whether a material or non-material solution will fulfill a capability gap, and then forward its recommendation up to the Marine Requirements Oversight Council (MROC; USMC, 2008a).

Once the MROC approves a material solution, the acquisition process for the equipment branches out into a series of tangential activities managed by either the Marine Corps Systems Command (MCSC; for land-based equipment) or NAVAIR (for all aircraft). Both MCSC and NAVAIR report directly to the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN[RDA]), shown in Figure 5, and work together alongside CD&I/MCCDC as needed to provide the Marine Corps warfighter the capabilities to execute missions efficiently and successfully. Before 2007, Marine Corps UASs were managed by MCSC under Product Group 11 (PG-11) for MAGTF Command and Control (C2), Weapons Sensors Development and Integration (MC2I).

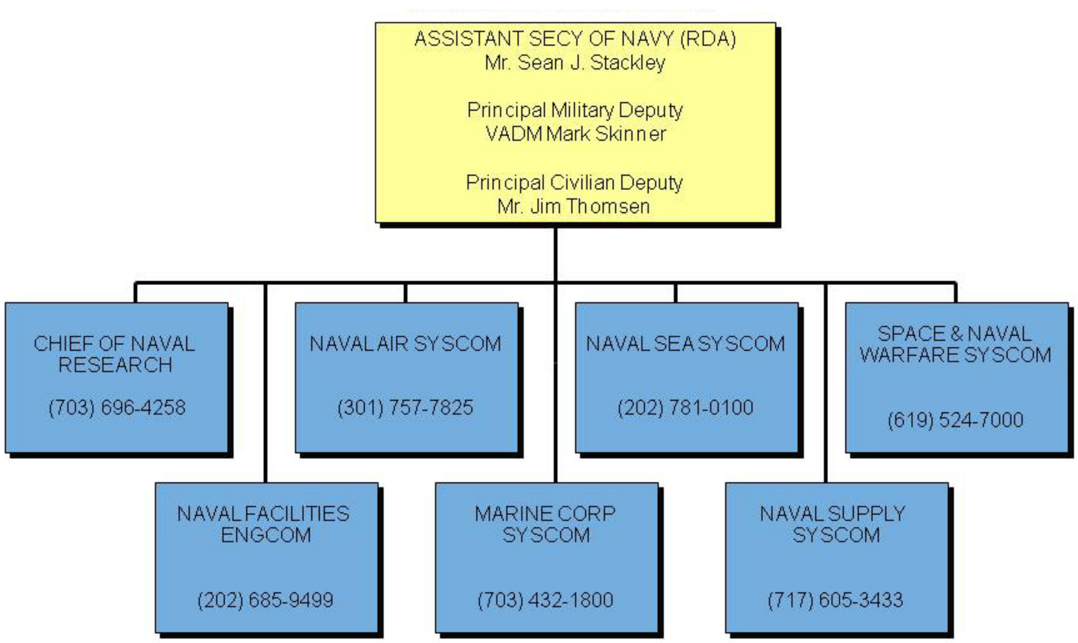


Figure 5. Department of the Navy Acquisitions Systems Command Structure (From: ASN[RDA], 2011)

Today, NAVAIR's Program Executive Office for Unmanned Aviation and Strike Weapons (PEO[U&W]) acts as the Marine Corps' acquisition advocate for UASs. PEO(U&W) oversees 10 program offices responsible for meeting the cost, schedule, and performance requirements of their assigned programs. Only one of the 10 program managers deals directly with the Marines' current unmanned systems of record. A Marine colonel is currently assigned the leadership and management responsibilities of PMA-263, which governs all efforts associated with the acquisitions process for the Navy and Marine Corps' Group 3 TUAS (Shadow), Group 2 STUAS (Scan Eagle), and the Group 1 SUAS (Raven). PMA-263 is also responsible for managing the other SUAS programs (T-Hawk and the Wasp) previously mentioned in this section. Figure 6 shows the interfaces between the PMA-263 and other external organizations.

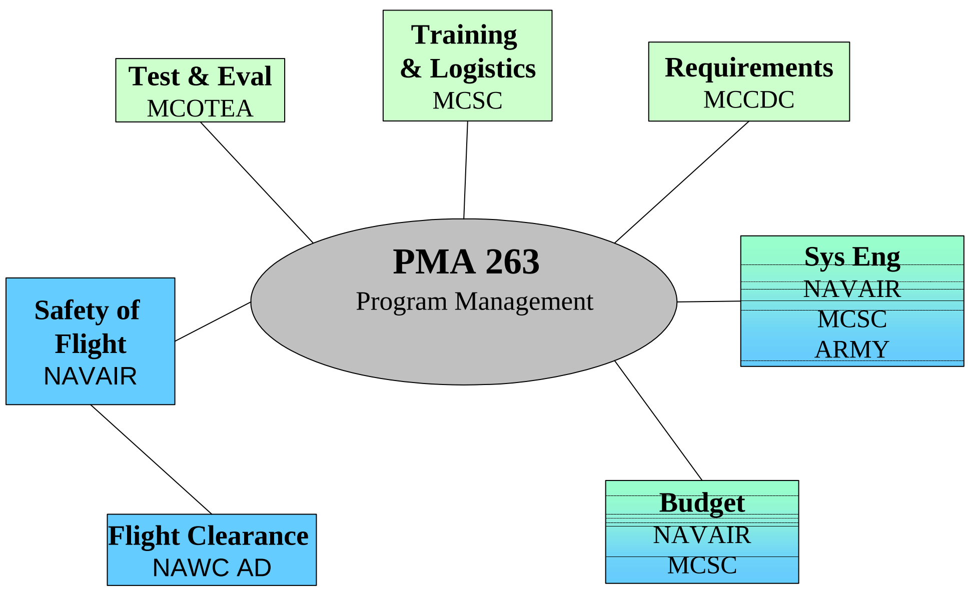


Figure 6. The Integrated Product Team for Group 1 UAS (From: MCSC, 2008a)

E. SUSTAINMENT

The estimated percentage of money spent on O&M of a typical weapon system averages 60% of the total lifecycle cost (LCC), but can account for as much as 80%.

> In general, during the lifecycle of a weapon system a significantly larger amount of money gets spent in operating and maintaining the system than acquiring it. Hence, efficient logistics systems, including transportation, inventory management, modifications and maintenance activities, are

> critically important for containing the lifecycle costs of weapon systems and for maintaining the highest level of military readiness given the extant fiscal constraints. (Apte & Kang, 2008, abstract)

Figure 7 depicts a notional profile of program expenditures by cost category over the system lifecycle (Matthews, 2011). With the increasing length of time the DoD retains its weapons systems in its inventory through programs such as the Service Extension Program (SEP), many weapon systems are experiencing greater percentages of the total LCC spent on O&M (Apte & Kang, 2008). Most weapon systems are designed for a lifecycle of about 20 years. Today's unmanned aircraft, however, are designed and manufactured incorporating operational lives of five to 10 years.

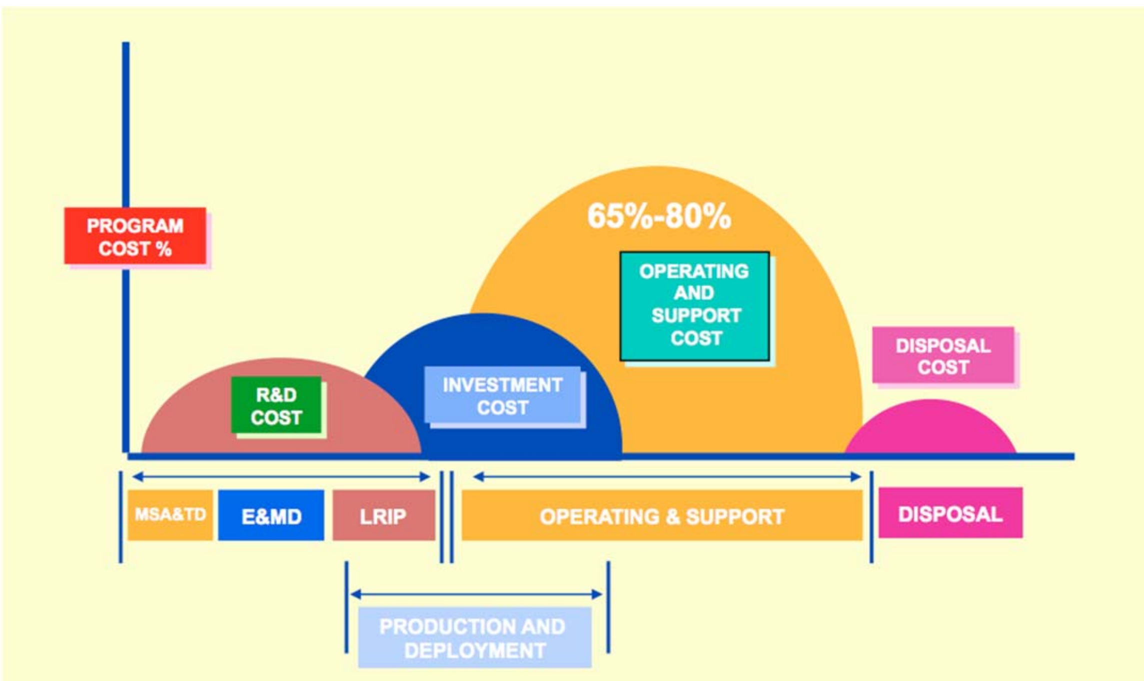


Figure 7. Illustrative Diagram of a Program Lifecycle (From: Matthews, 2011)

Before equipment is fielded, the DoD requires that all military materiel have plans for sustainment. The sustainment plan should be designed to best support the system throughout its life cycle (Under Secretary of Defense (Acquisitions, Technology and Logistics) (USD[AT&L]), 2008, p. 28). According to the USD(AT&L), lifecycle sustainment planning will be flexible and performance-oriented with considerations that

> include supply; maintenance; transportation; sustaining engineering; data management; configuration management; HSI [human systems integration]; environment, safety (including explosives safety), and occupational health; protection of critical program information and anti-tamper provisions; supportability; and interoperability (USD[AT&L], 2008, p. 28).

This thesis assumes the term *sustainment* relies mainly upon supply and maintenance considerations. The DoD's policy for maintenance of military materiel, as laid out in DoD Directive 4151.18, states that military maintenance programs should achieve inherent performance, safety, and reliability levels of the equipment. The policy also states that, regardless of where maintenance occurs, "throughout the life cycle of military materiel, maintenance programs shall be adjusted periodically to improve maintenance agility, increase operational availability, and reduce life-cycle total ownership costs" (USD[AT&L], 2004, p. 2). However, it is important to understand that as the lifecycle of a weapon system progresses, the decisions on its support design exponentially affect the total cost of sustainment and at some point, the cost becomes unchangeable (see Figure 8). Therefore, those who design sustainment strategies and those with decision-making authority have the difficult position of balancing trade-offs between spending less money for a potentially less effective support system or investing more money for more comprehensive support. The grim reality is that acquisition and military leadership working within a budget need to learn how to make sustainment decisions as early as possible in the system's life in order to spend less while attaining the best support.

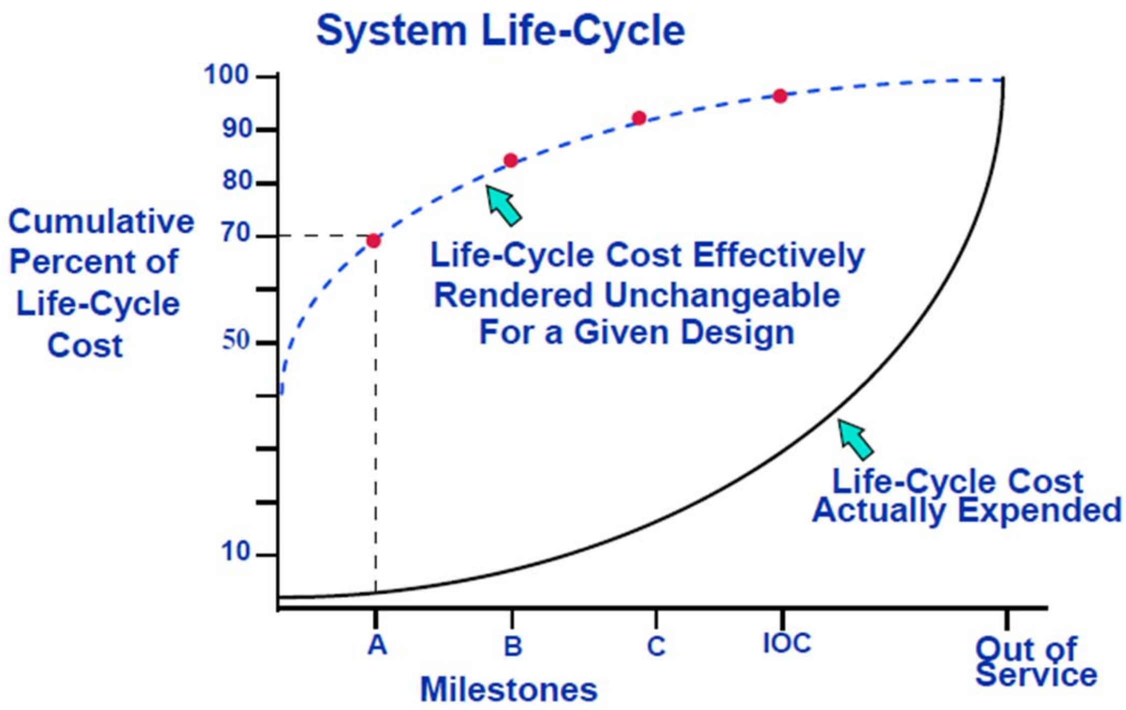


Figure 8. Illustrative Diagram of Decision Timing on Lifecycle Cost (From: Acquisitions Department, 2011)

The DoD's maintenance policy requires that the sustainment program "employ maintenance concepts that optimize process technologies, organizational structures, and operating concepts to deliver efficient and effective performance to the operating forces" (USD [AT&L], 2004, p. 2). Determining whether a piece of equipment is inherently Governmental or commercial helps determine the type of support strategy chosen or designed to sustain it throughout its lifecycle. The support structure must, as it states in DoDD 4151.18, "provide organic maintenance for inherently Governmental and core capability requirements" (USD[AT&L], 2004, p. 2) while "non-core capability requirements shall be satisfied using competitive sourcing, as appropriate … to lower costs and improve performance across the full spectrum of maintenance activities" (p. 2). From within this guidance, there are many maintenance support structure alternatives for sustaining a weapon system during its life cycle—including organic or unique military capabilities; performance-based logistics arrangements; commercial sector support; partnering; and competition.

Due to the rapid ascension of UASs on the modern-day battlefield and the associated rate of technological innovation, the military increasingly relies upon commercial support. Compared to the larger, military-equipped UASs, small UASs are typically COTS systems that are updated and modified relatively frequently. Therefore, there has not been much emphasis on establishing a robust organic capability to sustain these smaller systems.

An organic sustainment option is a military-oriented supply and maintenance construct in which service members conduct the maintenance and provide supply support using the military service's procedures and resources. The other primary option to sustaining the smaller UASs is the purchase of contracted logistics services whereby the supply and maintenance of a system is provided through some non-governmental commercial agency, which typically involves the OEM. However, there are hybrid alternatives that partner the military and government with commercial service providers in what is sometimes called a modified CLS.[1]

Regardless of alternatives, cost and performance analyses are conducted during the acquisition process to determine the best value sustainment option, for which there are numerous considerations. Generic operating and support (O&S) cost structure elements include support personnel; unit-level consumables; intermediate-level maintenance; depot-level maintenance; contractor support; sustainment support[2]; and indirect support (DoD, 2012, Chapter 3.1.3.3).

Especially applicable in today's technically-advanced, fast-paced, and persistent battle space, American warriors need to maintain a competitive advantage over their enemies, assured that the established supply chain and maintenance construct can support them and their equipment. In every aspect of program management, the DoD acquisition workforce is constantly challenged to balance cost, schedule, and performance. In a

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[1] There is also a third standard option when a Service relies on the logistics infrastructure and activities of another Service. This, is typically managed through a memorandum called an interservice support agreement (ISA or ISSA) and is applicable for supporting common systems and when activities are aboard common installations or in common facilities.

[2] Sustaining support includes the cost of replacement support equipment, modification kits, sustaining engineering, software maintenance support, and simulator operations provided for a defense system.

business transaction, better performance generally warrants a higher initial price, as is the case not only at the onset of an acquisition initiative, but also throughout its lifetime. However, Government and military practitioners involved with the acquisition process understand that there is increasingly limited capital available to today's heavily-scrutinized defense department. Therefore, not only is sustainability a key performance parameter (KPP) among the requirements for today's weapon systems, so is affordability. If acquisitions leaders fail to establish a proper sustainment strategy that is balanced against costs, they could severely affect the quality of support provided for the weapons system to the detriment of warfighting capability.

III. THE USMC RAVEN PROGRAM

A. HISTORY

In this section I expand on the background presented in Section B of Chapter II and specifically focus on the Raven program.

1. USMC SUAS Origins

The foundation for the current SUAS dates to the Marine Corps' Airborne Remotely Operated Device (AROD) Program initiated in the early 1980s. The AROD project was as part of the Exploratory Development Surveillance Program. It was continued as part of the 1986 Ground/Air Tele-robotics Systems (GATERS) Advanced Technology Demonstration program together with the ground-based Tele-operated Vehicle (TOV). The AROD provided airborne reconnaissance and surveillance to the Highly Mobile Multi-Wheeled Vehicle (HMMWV)-based TOV, which was developed to perform remote RSTA of up to 30 km (Space and Naval War Systems Command [SPAWAR], n.d.). The aerial device was intended to pass imagery information as well as perform radio relay and electronic warfare functions (Richardson, 1988, p. 22).

The first AROD was a small ducted-fan VTOL air vehicle that could provide short-range aerial surveillance and, weighing only 40 pounds, was small enough to be carried by one person. The AROD was connected to and controlled from a portable ground control station (GCS) by a tethered fiber optic data-link cable that provided the unit with electrical power and facilitated image relay and communications; the communications were backed up by a radio link. The aerial device had limited endurance and payload capacity, restricted by the 5 km reel of optical fiber it carried to support a 2 km round trip or 5 km one-way mission. At a price of about $3000, the AROD was essentially a "combat expendable drone" (Richardson, 1988, p. 22). Although developers successfully tested some its capabilities in free flight, the GATERS program canceled the AROD system due to a combination of limited funding and its instability in flight (SPAWAR, n.d.).

In 1989, the winner of a DoD competition for the Very Low-Cost UAV Program (VLC UAV) was AV's 1986 private venture, the FQM-151 Pointer, which became the first hand-launched, back-packable, fixed-wing UAS employed initially by the Army and Marines. The Pointer was first operationally deployed in 1991 in support of Operation Desert Storm alongside its larger AAI Pioneer UAV counterpart. As described earlier, the Pointer served the Marines until 2008 when it was phased out and replaced by the Raven, though the Pointer still serves with Air Force and Special Operations units.

Nearly a decade after the competition for the VLC UAV, the Marine Corps drafted a Fleet Marine Force operational need statement (FONS) for an Interim Small Unit Remote Scouting System (I-SURSS) in 1999; the FONS outlined the need for a small hand-launched, re-usable, fully autonomous UAS with interchangeable modular payloads and a laptop computer–based GCS to provide over-the-hill RSTA and facilitate fire support missions (Hendrickson, 2008, p. 66). The Naval Research Laboratory (NRL) and the MCWL collaboratively created the Dragon Eye Program to demonstrate the integration of technologies into the I-SURSS. NRL built a scaled-up prototype version of its Micro Tactical Expendable (MITE) air vehicle, which was already under development for several years (Hewish, 2000). The Dragon Eye prototype made its first flight in May 2000 and in 2001, the Marines took delivery of the system for limited technical assessments.

In February 2002, an integrated product team (IPT) developed a draft evolutionary I-SURSS operational requirements document (ORD) that outlined an acquisition process to acquire and field a functional solution to the I-SURSS. The draft ORD specified five increments (Block 0 through Block 4). Blocks 0–1 addressed development of the aerial sensor; Blocks 2–4 addressed development of a "hand-emplaced and munitions emplaced sensor in addition to the aerial sensor" (MCSC, 2008a, p. 6).

In May 2002, the Marine Corps subsequently sponsored an industry-wide competition to decide the system's full rate production company—with each vendor delivering prototypes for evaluation. The prototypes were tested and evaluated by Marines during a limited objective experiment (LOE) using the performance criteria in

the draft ORD. However, the experiments involving the advanced prototypes were interrupted when in September 2002, 1st Marine Division (MARDIV), 1st Marine Expeditionary Force (MEF) routed a universal needs statement (UNS) calling for immediate Dragon Eye UAS support to the operating forces in Iraq. NRL redesigned the I-SURSS program to meet the urgent need by upgrading a group of pre-production systems and immediately deployed them to Iraq, where the Marines conducted extended user assessments concurrent with real-world missions until June 2003. Also in September 2002, MCSC began managing the I-SURSS program as an Abbreviated Acquisition Program (AAP) after the Director, MCWL and the CG MCSC reached an agreement to transition program management from MCWL.

In November 2003, the Corps awarded a sole-source contract to AV to optimize the design and manufacturing processes (Hendrickson, 2008, p. 66), and in September 2004, the SURSS ORD was finally adopted. In December 2004, the Milestone Decision Authorities (MDAs), MCSC and PEO(U&W), established SURSS as a PoR, approved production to achieve the acquisition objective, and designated SURSS Block 0 as an Acquisition Category (ACAT) IV(T) program. The Marine Corps employed Dragon Eye until 2008, after it had already begun research in 2006 for and approved its replacement to fulfill the Block 1 SURSS upgrade.

2. RQ-11 Raven Origins

There is a comprehensive study of the Raven UAS documented in the 2011 Acquisition Research Program symposium paper “Emerging Patterns in the Global Defense Industry,” authored by Raymond E. Franck, Ira Lewis, David Matthews, and Bernard Udis. I derive the majority of this section’s information regarding the system’s early acquisition developments from that report.

One of the numerous concurrent UAS initiatives within the DoD in the 1970s and 1980s was when the U.S. Army sought to develop and field a relatively small unmanned RSTA capability directly into the hands of its artillerymen to enhance their target acquisition abilities. An early project, initiated as a joint venture between the Army and the Lockheed Missiles and Space Company Inc. in 1974, was a small battlefield RPV

designated the MQM-105 Aquila. However, after successful initial stages, the Aquila eventually lacked the technical performance to pass the testing criteria and the program was subsequently cancelled in 1984. This was due to a number of reasons, one of which was requirements creep. After developers increased Aquila's size from its original 146 pounds to 250 pounds, it was still unable to physically support the weight of a growing number and type of user-required sensors (Franck, Lewis, Bernard, & Matthews, 2011, p. 65).

Though the Army investigated unmanned technologies for decades before and after of the Aquila program, the requirements for a small UAV (SUAV) capability for dismounted forces fighting in urban terrain were finally matured and officially demonstrated during the FY1998–2002 Military Operations in Urban Terrain, Advanced Capability Technology Demonstration (MOUT ACTD)—long after relatively small UAVs were operational.

Following the MOUT ACTD program's demonstration in 2000 and the extended user evaluations, the AV-manufactured FQM-151 Pointer had proven to be a clear success by meeting the majority of the SUAV program's 33 acquisition-stated requirement areas. Although it finished third among a field of 27 other technological solutions, it was chosen to advance through the extended ACTD. However, even after further development, the Pointer still had important deficiencies; it was too big and overly heavy (Franck et al., 2011, pp. 66–67).

The ACTD spurred SOCOM interest based on the recently published Special Operations Miniature Robotic Vehicle Capstone Requirements Document (SOMROV CRD) in September 2000 (USSOCOM, 2004). The CRD specified requirements for a family of small, light, ground, air, and maritime robotic vehicles. Also initiated in 2000 was a derivative of the SOMROV CRD, the USSOCOM for the Rucksack Portable Unmanned Aerial Vehicle Operational Requirements Document (ORD RPUAV) that further articulated the small UAV requirement (USSOCOM, 2004).

The ORD outlined that the small UAV system should be "capable of rapid launch from field locations, short operating ranges, extended mission duration, and a low profile

recovery from unprepared areas," while "providing dedicated imagery and sensor data to the small unit for over-the-hill and around-the-corner employment." (USSOCOM, 2004, pp. 5–7) Furthermore, it stated the system should "have the ability to be carried, launched, controlled and recovered by a single operator" (USSOCOM, 2004, pp. 5–7). At the onset of both OEF and OIF, SOCOM procured a limited number of Pointer systems to satisfy a combat mission need statement (C-MNS; USSOCOM, 2004, p. 4).

Having its own Acquisition Executive with independent authority, SOCOM provided momentum to the UAS program demonstrated at MOUT ACTD. Subsequently, AV was awarded a contract in 2001 (with the U.S. Army Natick Labs) to research and develop a smaller, lighter air vehicle with the same capabilities as the Pointer. SOCOM was able to bypass the traditionally cumbersome DoD acquisition process to proceed with the development of the UAS faster and less formally using system requirements derived through the spiral development process (Franck et al., 2011, p. 69).

Generally, spiral development is an iterative cycle in which first, the system concept is introduced to users; second, the users define system requirements; third, a prototype is designed based on user requirements; fourth, users evaluate the requirements and prototype; and fifth, users generate new or updated requirements and design guidelines based on previous steps. The process is then repeated; each successive design cycle gets closer to the final product. In this case, AV's Pointer was the initial prototype—providing SOCOM an initial reference point for development and feedback (Franck et al., 2011, p. 70).

Using the spiral method in this case, SOCOM and Natick made substantial improvements in making relatively low-cost prototypes and quickly ending with a user-accepted product. The resultant platform was the Flashlight SUAV that, after successive feedback and development, yielded the initial variant of the RQ-11 Pathfinder Raven UAV (Franck et al., 2011, p. 67). Around the time it bought several Pointer UAVs in response to several urgent C-MNS, SOCOM also procured the Raven in 2002 for missions in support of OIF and OEF. Then, the U.S. Army's Program Manager for UASs (USA PM-UAS), with renewed interest and funding, sent an improved Raven configuration based on user feedback into production a short four months after low rate

initial production (LRIP) of Raven Block I began in May of 2003. As noted earlier with the special operations acquisitions process, urgency oftentimes outpaces the traditional process, as was demonstrated when the RPUAV ORD was officially signed in 2004, two years after the actual procurement of the system that met its requirements (Franck et al., 2011, p. 70). Incidentally, approval of the RPUAV ORD occurred in parallel with but independent of the approval of Marine Corps' I-SURSS ORD in 2004.

Because the Raven was largely developed and procured through the USSOCOM acquisitions process, integrating the system into the mainstream Army proved difficult. The system lacked any formal doctrine usually developed through traditional acquisition channels. When Army leadership and operating forces realized the Raven's effectiveness, "it was outside of the mainstream research, development, and acquisition system" (Franck et al., 2011, p. 71). Therefore, the Army struggled to quickly develop doctrine and incorporate it into their formal training pipeline. However, after years of use and refinement, the Raven has become the foundation of the Army's small unit organic intelligence gathering tactics. The Army has continued its successful working relationship with AV for the Raven since 2003, from which both the Army and Marine Corps are beneficiaries.

3. The Marine Corps Adopts Raven

In establishing the I-SURRS ORD, the Marine Corps planned to pursue a rapid acquisition approach to quickly field new UAS technology and capabilities to its warfighters. Therefore the Group I IPT planned to execute an evolutionary acquisition approach with two incremental developments to meet final desired SURSS requirements. AV's RQ-14 Dragon Eye fulfilled the Block 0 increment, which enabled the Marines to field a capability as quickly as possible. Dragon Eye represented 75% of the Marines' desired final capability; however, the second increment, Block 1, was planned to fulfill 100% of the Marines' requirements.

In 2006, the Marine Corps changed direction somewhat and searched for alternatives to fulfill the SURSS Block 1 requirements, thereby eliminating the interim status of the program. It chose to both adopt the 2004 USSOCOM RPUAV ORD and

utilize the Army's procurement of an equivalent system—RQ-11B Raven. This approach reduced costs and risk because the Raven had already entered full rate production (FRP) and was based on mature technology. Subsequently, the Corps received an initial fielding decision in the second quarter of FY2008 and a full fielding decision in the fourth quarter of FY2008, both of which built on the acquisition decisions already made by the Army, shown in Figure 9 (MCCDC, 2008, pp. 9–11).

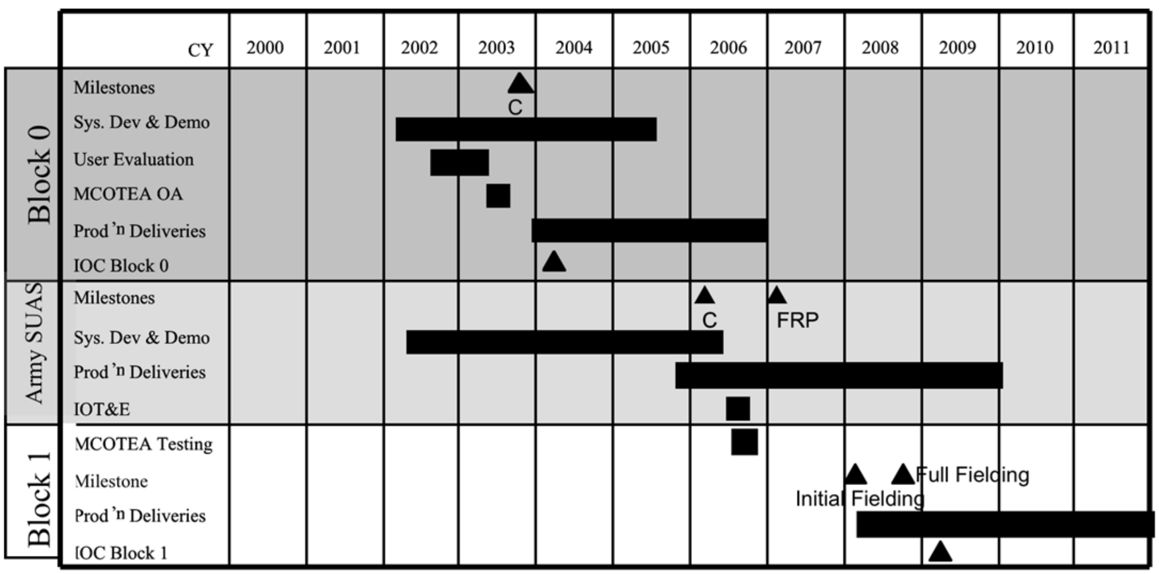

Figure 9. SURSS Program Schedule (From: MCCDC, 2008)

The Marine Corps procured the Raven systems in parallel with the Army and USSOCOM systems on a modified firm-fixed price production contract with AV, within which there was sufficient AV production capacity to meet the Corps' procurement goals through the expiration of the contract in 2010. The Marine Corps negotiated a support strategy that maximized the reuse of Army-supplied materiel and delegated systems engineering responsibility to the Army (MCCDC, 2008, p. 16). However, the Marines incorporated its Group I IPT into the Army's IPT as a voting member on the combined Configuration Control Board (CCB). The agreement stipulated that future changes to the Raven system program be vetted through a joint configuration control process that ensured Marine Corps requirements continued to be met (MCCDC, 2008, p. 12).

It was at this time (October 2006) that program management of the Marine Corps' UAS acquisitions began transitioning from MCSC to PEO(U&W). PMA-263 and the USA PM-UAS began sharing program management responsibilities with the MCSC SURSS Project Office (PO). PMA-263 also established a Group I IPT, shown in Figure 5 in Chapter II, within the organization to facilitate the complex relationship between the numerous proponents and stakeholders (MCSC, 2008a, p. 7).

The MROC approved the Group I UAS Operational and Organization (O&O) Concept in September 2006, and it became the Marine Corps' source document describing Marine SUAS capability. The O&O also outlined SUAS key performance parameters, operational concept, logistics strategy, and initial fielding distribution throughout the Marine Corps (MCCDC, 2011).

B. RQ-11B RAVEN DIGITAL DATA LINK

In October 2008, less than a year after the Marine Corps reached IOC for the Raven, the USA PM-UAS approved (with PMA-263 concurrence) an engineering change proposal to integrate the upgrade from Raven's four- and eight-channel analog variants to AV's latest DDL-capability. With the planned procurement of the upgraded Ravens, the Army and Marine Corps decided to continue their relationship beyond the 2010 expiration of the original agreement and modified the contract statement of work (SOW; MCSC, 2011, p. 1).

AV's proprietary DDL is a small "broadband digital network node to enable enhanced command and control of a small UAS. The DDL is IP-based to enable maximum flexibility and interoperability between small airborne and ground systems with limited power availability, and bandwidth-efficient to maximize the number of systems that can operate within an area" (AeroVironment, 2011). The AV upgrade of Raven involves both retrofitting active analog systems in service as well as manufacturing new production units to meet Army and Marine objectives.

In 2011, PMA-263 updated the O&O to reflect changes in Raven's budgeting estimates, its concept of support, and the distribution of systems. Table 1 shows the Group I distribution. The current fielding plan for Raven is a continuation of the

schedule produced for the analog systems, although the initial fielding of DDL systems occurred in the third quarter of FY2011, with full fielding still planned for FY2014 (MCCDC, 2011, p. 6).

Table 1. Approved Acquisition Objective Distribution (After: MCCDC, 2011)

Destination	Qty
I MEF	100
II MEF	105
III MEF	53
MARSOC (Special Operations Command)	57
MARFORRES (Reserves)	71
MCSC/TECOM (Supporting Establishment)	17
WRMR (War Reserve Materiel Requirement)	58
Total	**461**

C. MISSION AND SYSTEM CAPABILITIES

1. Mission

The Raven's mission is to provide a low cost, low altitude, remote aerial "reconnaissance and surveillance, target acquisition (RSTA), force protection (FP) and convoy security, battle damage assessment (BDA), for light infantry, dismounted warfighters, and military operations in urban terrain (MOUT)" (AeroVironment, n.d.). For the Marines, the Raven provides organic OTH RSTA for the MAGTF's lowest level ground, aviation, and logistics combat elements (GCE, ACE, and LCE)—battalion-sized units and below. The Marine Corps has fielded most of its systems to infantry, light armored reconnaissance (LAR), and tank battalions, as well as smaller quantities to other units such as artillery battalions, Marine wing support squadrons (MWSS), combat engineer battalions (CEBs), headquarters and service (H&S) battalions, and Marine logistics group (MLG) units. Figure 10 depicts a Marine hand-launching the Raven in the field. According to a 2009 report on the Raven's employment during OIF by the Marine Corps Center for Lessons Learned (MCCLL), the Raven augmented the use of theater- and national-level ISR assets.

Figure 10. A Marine Hand-Launches Raven UAS (From: AeroVironment, n.d.)

The Raven did not reduce the Marines' reliance on non-organic assets, but having access to available higher level ISR assets "did not minimize the effectiveness or value of a dedicated battalion and company level ISR platform" (MCCLL, 2009, p. 8). The Raven was employed by Marines in Iraq to support a variety of missions (MCCLL, 2009, p. 9):

- Forward Operating Base (FOB) security;
- surveillance of selected avenues of approach, or rat lines;
- reconnaissance prior to raids, and cordon and knocks;
- population observation (pattern of life analysis);
- deception operations;
- cache sweeps;
- patrol over watch.

2. Components and Capabilities

The Raven is battery-powered using either a single-use LiS02 battery or a rechargeable LiIon battery via DC or AC inputs. The different payloads consist of

various sensors and cameras that provide visual feedback to the ground control station (GCS), which is used to control the aircraft, load missions, and display the near-real-time video. Remote units can also gain access to video and location information by using a remote video terminal (RVT), which functions much like the control station. The Raven system also enables the operator to conduct training by connecting the GCS to a standard laptop computer by using a software simulation package. The GCS includes telemetry technology that allows the operator to control and monitor the SUAS from a distance via radio wave or network transmission and reception, which also provides the system a capability of both manual and autonomous flight. The hand-held control unit is the operator's display and entry/control device, while the radio frequency (RF) receiver/transmitter (R/T) unit contains the up- and downlink communications radios. The Raven B cruises at about 30 mph for up to 90 minutes (MCSC, 2008a).

One Marine Corps SUAS Raven system consists of the basic components listed in Table 2, with an additional initial spares package (ISP) for operation and support of the basic system (MCCDC, 2011, p. 2).

Table 2. RQ-11B Raven System Components (After: MCCDC, 2011)

Description	Qty
Air Vehicle (excludes battery and payload)	3
Electro-Optical (EO) payload (forward and side looking)	3
Infrared (IR) payload (side looking)	2
Infrared (IR) payload (forward looking)	1
Ground Control Station (GCS)	2
Remote Video Terminal (RVT) (spare)	1
RSTA Kit	1
Field Repair Kit (FRK)	3

The following are descriptions of the Raven SUAS components and their illustrations, shown in Figure 11 (PEO AVN, 2007a, pp. 4–5):

- GCS and RVT: The Ground Control Station (GCS) and Remote Video Terminal (RVT) are essentially identical and provide the same functional capabilities for the SUAS. The components of each GCS/RVT are an RF Unit with antenna, hub, cables, and a hand controller.

- Air Vehicle: The air vehicle is designed with modular components (fuselage, center wing, left wing tip, right wing tip, tailboom, stabilator, battery, and payload) and can be snapped together without tools and ready for flight in under three minutes. The air vehicle consists of the airframe, avionics, navigation, and power components/subsystems required for flight. It is hand-launched and has an autonomous landing capability. The air vehicle accommodates modular EO and IR payloads.
- Payloads: The SUAS includes two separate payloads. The electro-optical (EO) payload provides imagery during daylight conditions and the infrared (IR) payload provides imagery during either daylight or night conditions. These payloads provide video imagery downloaded to the GCS and RVT. These payloads are modular and can be snapped on or off without the use of tools.
- ISP: The initial spares package (ISP) contains the battery chargers, batteries, kits, and spares required to sustain the system in the field.
- FRK: The field repair kit (FRK) is a small, lightweight kit that contains the components (e.g., propellers, stabilator clips, tape, etc.) and tools that the operators require to repair normal damage encountered during landings.

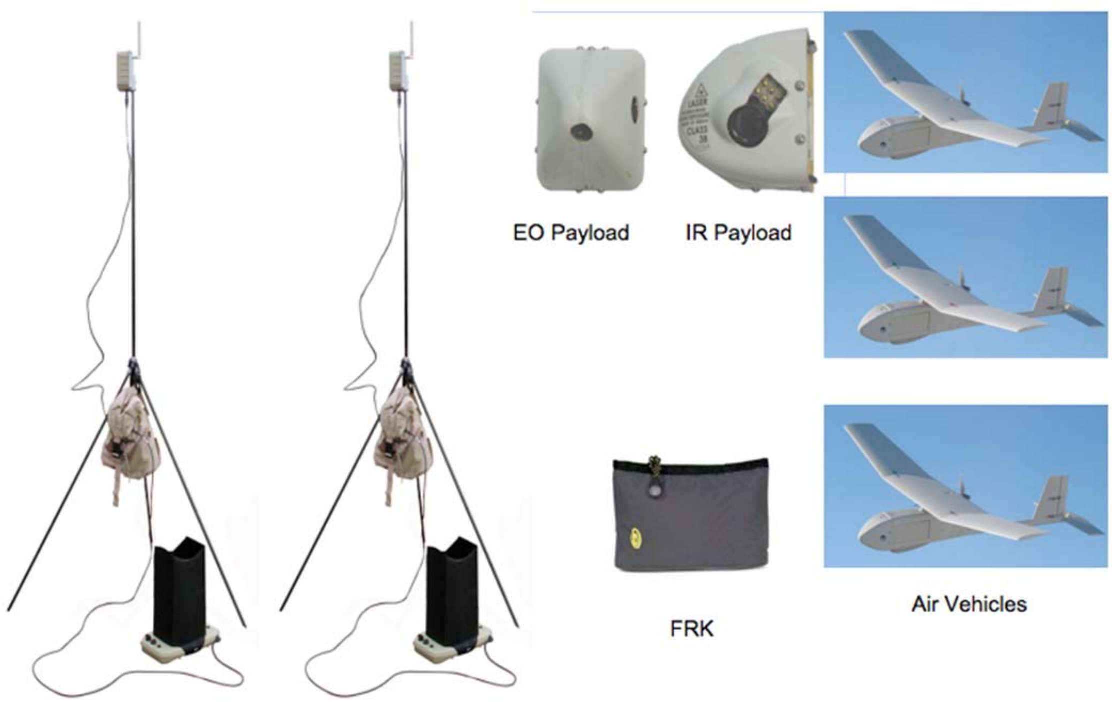

Figure 11. Basic RQ-11B Raven SUAS Illustration (From: PEO AVN, 2007a)

AV advertises Raven as most advanced small UAS in the DoD's inventory. It is touted as rapidly-deployable and highly-mobile, providing U.S. forces aerial observation

(day or night by delivering real-time color or infrared imagery to the ground control and remote viewing stations). AV lists describe it as a small, lightweight, hand-launched ISR air vehicle with simple operation—that includes autonomous navigation, auto-land (deep stall) capability, and an interoperable system interface (AeroVironment, 2010). Table 3 lists the Raven's technical specifications.

Table 3. RQ-11B Raven's Technical Specifications **(**After: AeroVironment, 2010**)**

Characteristic	**Capability/Measurement**
Range	10 km
Endurance	60–90 minutes (rechargeable battery)
	80–110 minutes (single use battery)
Speed	32-81 km/h, 17-44 knots
Operating Altitude	100-500 ft (30-152 m) AGL (typical)
	14,000ft MSL (max launch altitude)
Wing Span	4.5 ft (1.4 m)
Length	3.0 ft (0.9 m)
Weight	4.2 lbs (1.9 kg)

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IV. SUSTAINMENT OVERVIEW AND ANALYSIS

Marines employing the Raven during its early fielding in 2008 underlined the state of the supply and maintenance situation by summarizing the following observations in the previously cited 2009 MCCLL report:

> Confusion existed among some units regarding the supply and support system when repair and troubleshooting of the [Raven] system were required. Logistical support of the system was not standardized with one battalion assigning it to their supply section while the other battalion assigned it to their communications section. (p. 2)

The MCCLL report also listed other important lessons that 1st Battalion, 4th Marines (1/4) in Fallujah and 2d Battalion, 23d Marines (2/23) in Ramadi had learned through their combat experiences, emphasizing the importance of having an effective, standardized, and dependable sustainment structure. Although they offered some recommendations for improved support, the Marines of 1/4 and 2/23 could only reflect the surface issues surrounding the apparent insufficient support of the Raven.

Among the major issues the Marines cited were

- no standard operational logistics chain among units,
- lack of universally defined level of repair,
- no clear communication channels regarding support,
- excessive lead-time for requisitioned repair parts, and
- not enough training on operation and troubleshooting.

A. SUMMARY SUPPORT STRATEGY: ANALOG VS. DIGITAL DATA LINK

As a brief overview of the evolution of sustainment for the Marine Corps' Raven system, MCSC and NAVAIR programmed the sustainment of the system utilizing a combination of the organic-CLS construct throughout its life cycle. In the four years the Marines have employed the Raven, the system's support has been neither exclusively organic nor entirely contracted logistics. Generally, the two alternatives used by MCSC and NAVAIR to support the RQ-11 Raven throughout its life cycle have been hybrid

solutions using varying degrees of the organic-CLS construct—in the beginning the construct leaned more on organic support than CLS, but; now the opposite is true.

While initiating the contract for the Raven in 2007, MCSC and NAVAIR did not plan or implement CLS to maintain the SUAS below the depot level of repair. According to the 2008 Marine Corps' Fielding Plan, MCSC and NAVAIR used the same firm-fixed price (FFP) contract as the Army for production and post-production efforts in support of the analog Raven. The contract vehicles for standard post-production support included operator training, engineering support, and technical support. However, after feedback from the MARFORs (the 1st Marine Division G-2 Intelligence Chief and the 2009 MCCLL report), NAVAIR analyzed the support plan for the Raven and researched strategies to improve the sustainment construct and performance.

After coupling its qualitative analysis of user feedback with the quantitative analysis performed by the Army PM-UAS in 2010, NAVAIR made the decision to initiate a modified CLS contract with AV under the Army's prime contract. NAVAIR negotiated the CLS contract in consonance with the retrofit and fielding of the new DDL-upgraded Raven systems effective in mid-2011. The source of NAVAIR's quantitative analysis came from the Army's SUAS product manager, who consolidated Army-generated input through the 2007 core depot assessment (CDA) and the 2007 best value Analysis (BVA) for the Pathfinder Raven, RQ-11B.

B. SUSTAINMENT ANALYSIS UNDER DOTLMPF FRAMEWORK

The Joint Capability Integration Development System (JCIDS) addresses the DoD's capability shortfalls or gaps by using a capabilities-based approach to requirements generation and uses the DOTMLPF framework to analyze potential solutions to fill those gaps (JCIDS, 2012). The JCIDS process provides a joint venue using common vocabulary for people working within its construct. The acquisition proxies representing the Services and Combatant Commanders participate in the JCIDS process to study and develop solutions encompassing any combination of tenets that make up DOTMLPF.

For this thesis, I use the DOTMLPF framework as a lens to analyze the evolving sustainment solution for the Raven. The framework facilitates the analysis of capabilities by asking questions that help identify the key enablers of a capability.

Where DOTMLPF definitions traditionally address operational capabilities and requirements, the following analysis more narrowly focuses on sustainment capabilities; however, some areas do overlap both aspects. In the following sections I provide an adapted definition of each area and outline what developers planned for fulfillment of the support requirement, how or if the solution changed from the original design, and conclude with my assessment. In this section my analysis is primarily substantiated through official acquisitions documents and deduced from the recognized lessons learned through the experiences of Marines and experts who either use or support the Raven system.

1. Doctrine

Doctrine is the codification of fundamental principles that guide the employment of forces in coordinated action toward a common objective. Doctrine includes universally approved documents outlining the way sustainment forces support the warfighter, including tactics, techniques, and procedures (TTPs) and operating procedures.

a. Fielding and Support Plans

The Army's PM-UAS, NAVAIR, MCSC, and MCLC collaborated with AV to develop the foundation for the supply and technical manuals, which provide comprehensive guidance and instruction on how to best execute the sustainment of the Raven. Most of the information derived for this analysis comes from these documents and provides the greatest in-depth detail on the Raven's support structure. The USMC fielding and support plans outlined the logistical support of Raven B systems, which both the 2008 and 2011 set of documents stated is a mix of CLS and organic support for the life of the system.

In the initial fielding of the analog Raven systems in 2008, the Marine Corps concept of maintenance for Raven systems consisted of three levels: organizational (O), intermediate (I), and depot (D). MCSC planned on implementing organic support at both the O and I maintenance levels. The Marine concept for Raven maintenance was different than the Army's, which was field (organizational) and sustainment (depot) maintenance. The Army excluded the concept of organic intermediate maintenance for its Raven systems. Both Services agreed that the military operator would perform O-level tasks, while the prime contractor or organic depot (for the Army) performed D-level maintenance.

AV designed the Raven as an easily-maintainable system, enabling typical user-level repair in less than 15 minutes. The major components are modular line replaceable units (LRUs) and non-reparable LRUs (NLRUs) capable of being quickly removed and installed; furthermore, LRUs are composed of shop-replaceable units (SRUs) and non-reparable SRUs (NSRUs), and SRUs are composed of consumable parts.

(1) Organizational-Level (O-level) Maintenance. The organizational support strategy relies upon the Raven operator to perform the lowest level of maintenance using consumables or the supply of LRUs. O-level maintenance consists of inspecting, cleaning, and performing operational test procedures and preventive maintenance checks and services as well as limited corrective maintenance. The operator has limited capability for repair including corrective maintenance for basic airframe maintenance and limited removal and replacement of system LRUs. Operators are responsible for fault isolation to a replaceable assembly or component and for removing and replacing the assembly or component to restore the system to full operational capability. Operators have limited consumables and LRUs in the ISP and FRK and replenish their supplies through the standard supply system. Hardware requiring maintenance beyond these tasks is evacuated to the intermediate supply activity for an exchange.

(2) Intermediate-Level (I-level) Support and Maintenance. The difference between the Marine and the Army maintenance concepts was the establishment of I-level supply and maintenance tasks. I-level support consisted of a

component direct exchange function performed by the intermediate supply activity and I-level maintenance. The I-level repairs basically included removing and replacing the failed SRU and the repair of the SRU through the removal and replacement of the failed part. Other specific tasks included limited structural repair to the air vehicle, limited internal wiring repair, circuit card replacement, motor and controller replacement, and replacement of cameras in the nose cones. The parts and units determined physically non-reparable (NLRUs and NSRUs) or not economically reparable were discarded according to supply instructions. In the early establishment of the program, initial I-level repair was expected to be minimal until required repair parts were available in the initial issue provisioning (IIP). Therefore, interim I-level support involved utilizing the Army FRA for deployed Raven systems or the AV repair facility. Any LRU or SRU that required maintenance tasks beyond the skill of the I-level mechanics was shipped to the D-level maintenance activity.

(3) Depot-Level Support and Maintenance. The 2008 plans included an interim agreement with the Army's PM-UAS to provide D-level support by the Army's contracted forward repair activity (FRA) deployed systems and at the contractor's repair facility for Raven training systems in the U.S. However, this was an interim arrangement until the Marine Corps could establish a plan for long-term depot support of Marine Ravens. MCLC had the long-term responsibility for providing D-level supply support.

Although the Raven's logistics footprint is small and limited at the O-level to the extent of transportation of spares and consumables by the operator, the I-level and depot level (D-level) activities maintained more substantial quantities of supplies. A diagram of the basic flow of organic support and maintenance activities as planned in 2008 is illustrated in Figure 12.

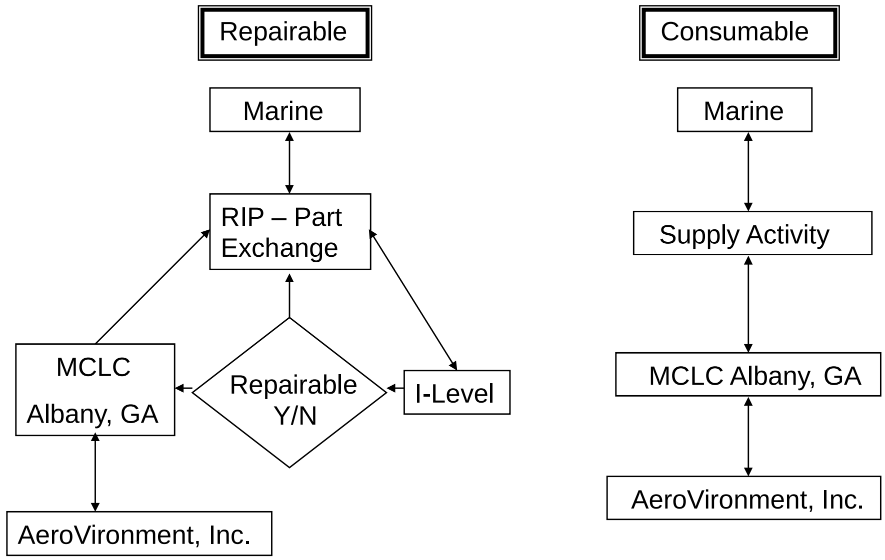

Figure 12. Diagram of Organic Analog Raven Supply and Maintenance Flow

The 2011 support plan restructured the sustainment agreement between the Marine Corps, Army, and AV in response to the previously mentioned reports of underperformance in support. As the most immediate remediation, NAVAIR entered into an arrangement with AV, who now performs more logistical support for the Marine Raven DDL systems under the current modified CLS contract. The contract awarded in 2011 mitigates the previous agreement with the Army PM-UAS and established dedicated capabilities through an FRA and CONUS repair facility for Marine Corps Ravens. This specifically included elimination of the Marine organic capability providing I-level maintenance and D-level supply. The contract facilitated a more exclusive relationship between the Marines and AV for field-level sustainment above the operator's capability. A diagram of the current modified flow of contractor supply and maintenance activities supporting reparable and consumable parts for both deployed and CONUS Raven DDL systems is illustrated in Figure 13.

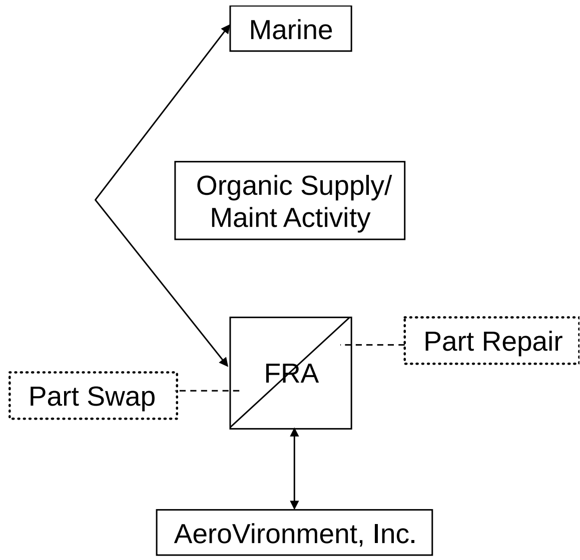

Figure 13. Diagram of Modified CLS Raven (DDL) Supply and Maintenance Flow

b. Supply Instructions

In 2007, NAVAIR collaborated with MCLC to create and provide instructions detailing supply processes and procedures for Marines operating and supporting the Raven. The supply instruction (SI)-11015B-OD/1 outlined responsibilities for using units, supporting units, and the supporting establishment including administrative requirements to facilitate the requisition and disposition of Raven supplies (USMC, 2007).

c. Technical Publications

Both the Army and AV developed the Raven's O&M manual addressing the operation of the system and the maintenance requirements for the unit level. The manual is electronically loaded into the laptop computer issued with the fielded system and delivered to the users. PMA-263 approves modifications and continued development of the system, which are reflected in changes to the manual and distributed to the MCLC, who in turn distributes them to all registered users. AV also developed a maintenance supplement for the USMC Intermediate Maintenance Activity (IMA), which was also subject to changes by AV. Upon training of users, NAVAIR provides each student a copy of the supplement manual.

Changes to this supplement are updated through the USMC publications website; unit publications clerks bear the responsibility to update the unit's publications list.

d. Standard Operating Procedures

The Marine Corps warfighting publication (MCWP) 3-42.1, *Unmanned Aerial Vehicle Operations*, published in 2003, is the most current doctrinal publication the Marines maintain to address the fundamentals of planning and executing UAV operations. It gives Marine commanders general guidance on command, control, and communication relationships that frame the UAV operating and support structures within the MAGTF. It also provides operational and logistics support factors that the commander should consider when planning and executing UAV operations (USMC, 2003).

e. Doctrinal Analysis

In response to the 2009 MCCLL report and other observations that the organic supply and maintenance chain had shortfalls, there is no resounding evidence that suggests that there was a lack of doctrine or standard procedures in place as established by the supporting establishment (i.e., NAVAIR, MCSC, MCLC). A universally defined level of repair is clearly formed by the supportability plan for both maintenance and supply activities. The technical and supply manuals also created clear communication channels to both organic and OEM representatives regarding support. However, the issue regarding the lack of a standard operational logistics chain among units is more closely related to the subsequent analysis of organizational factors as there was an obviously delineated supply chain above the unit level.

Additionally, although there are detailed publications for operator sustainment of the Raven, MCWP 3-42.1 is an inadequate resource for commanders both in scope and detail as it only encompasses the fundamentals for operations employing unmanned systems in Groups 2 and 3. The publication falls short in providing guidance to commanders who have organic UAVs like the Raven and is limited in addressing factors outside the VMU operational relationship for intelligence gathering and logistics support.

Similarly, the Army publishes its doctrine on UAS operations for commanders in the field manual (FM) 3-04.155, *Army Unmanned Aircraft System Operations*. The Army approved its most recent publication in 2009, which superseded the prior edition from 2006. In it, the Army provides much of the same information as the MCWP 3-42.1 regarding command and control relationships as outlines guidance on support for planning and executing UAS operations. It incorporates more detail than the Marine publication and contains extensive instructions on processes for sustaining and operating all UASs in the Army's inventory, including the Raven B at the lowest echelon of its systems (US Army, 2009).

2. Organization

In this section I focus on analyzing how the Marine Corps organizes its sustainment forces to support the Raven. I include a brief examination of both the units designated to receive and provide support. The analysis specifically focuses on the GCE and LCE of the MAGTF because, although NAVAIR is the primary acquisitions agent for the Raven, the system is procured, operated, and sustained as a land-based or ground asset.

a. Fielding Concept

The fielding plan in both the 2006 and 2011 O&O stated that the Raven is fielded throughout the MAGTF with emphasis to the GCE maneuver companies. NAVAIR coordinated that the Raven systems be shipped to central holding and storage points identified by the major commands (MEFs, MARSOC, etc.). The plan then places responsibility upon the major commands to authorize release of the new systems to gaining units of their designation. There are no further requirements or directives from the Marine Corps supporting establishment regarding which units below the MEF receive the Raven systems, nor are there formalized documents at the MEF level outlining the distribution method.

b. Operating Organizations

The operator is at the lowest level of operating organization. However, the organization in which the operator resides could vary even within the same battalion, as the concept of operations for using the Raven and intelligence gathering assets is left to the discretion of each commander. The following statement is from the 2009 MCCLL report previously cited:

> The Raven B's were primarily employed at the infantry company and platoon level with a majority of operators residing in the CLICs [company-level intelligence cells] and battalion S-2 sections. Raven B responsibilities were assigned as a collateral duty for the CLIC personnel. The CLIC was determined to be the most appropriate and logical place to manage the UAS and integrate it into the overall company intelligence collection plan. (MCCLL, 2009, p. 12)

A CLIC is an ad hoc section of a Marine rifle company that serves as an organic intelligence cell providing the company battlefield situational awareness during "nearly constant noncontiguous operations—primarily patrolling" (Alles, 2006). The CLIC is not an official Marine Corps authorized organization, so it is typically composed of a handful of Marines assigned from existing company staff as a collateral duty.

c. Supporting Organizations

The operator is the primary O-level of support designated to maintain the Raven as outlined in the O&O. However, similar to the fielding concept, there are no orders or directives designating support at the unit level immediately above the operator's capabilities.

The 2008 support plan required that operators evacuate hardware requiring maintenance beyond the O-level tasks to the repairable issue point (RIP) at the MLG for an exchange. This sustainment construct also designated the intermediate maintenance activity as the electronic maintenance company (ELMACO) in the MLG responsible for the I-level reparable maintenance tasks. Interim support procedure for I-level support during 2008 were to utilize the D-level arrangement with the Army and AV. Again, the 2011 plan eliminated the organic I-level sustainment tasks.

While the Marine Ravens received D-level repair from the Army's FRA in Iraq for deployed Raven systems or at AV's facility for Ravens in CONUS in 2008, the MCLC and the Defense Logistics Agency (DLA) provided D-level supply support. However, the new 2011 CLS contract shifted D-level support from the Army FRA to a Marine-specific FRA in Afghanistan and from MCLC to a NAVAIR established supply support organization using government facilities and AV personnel in CONUS.

d. Organizational Analysis

None of the organizations designated above the O-level reported any problems supporting the Raven regarding management, functionality, or funds. While NAVAIR, MCSC, and MCLC issued very detailed and specific instructions on which organizations would provide support, a section of those instructions and manuals missed defining sustainment more clearly at the organizational level. However, in this case specifically, the responsibility was upon the MEF and its major subordinate commands to do so; they failed to provide a clear delineation on how to support the Raven systems above the operator level and below the I-level.

Tying in the previous analysis regarding the dated and insufficient MCWP 3-42.1, the guidance on the operation and support for commanders receiving the Raven was primarily left to the MEF, which was also given the responsibility to distribute the Raven systems to its major subordinate commands. This led to non-standardized distribution of systems in which some commanders issued Raven systems for use among the different unit echelons. The Marine Corps does not mandate the employment of CLICs with their self-established responsibilities regarding the SUAS, thus the operation of Marine Ravens ranges from the platoon level to the regimental level without a standardized operating or supporting framework among the various units.

The issue regarding the lack of a standard operational logistics chain among units rests mainly on the MEF and subordinate units and their lack of standardized guidance for supporting the Raven, which led to the confusion experienced by 1/4 and 2/23 in 2008. Commanders within the MEF and its subordinate units did not specify or

properly enforce standard unit-level supply and maintenance activities and procedures to facilitate an effective sustainment strategy at the organizational level.

3. Training

Training encompasses how the Marines prepare to perform their tactical jobs using instructional methods to instill skill and develop proficiency, including basic training, advanced individual training, unit training, etc. In this section I examine the operator and maintenance training for the Raven system.

a. New Equipment Training (NET)

When fielding new equipment, MCSC and NAVAIR establish, as standard practice, a mobile training team (MTT) to begin instruction almost immediately once the gaining unit receives the system. In 2008, the Raven B MTTs were typically made up of activated Reserve Marines and augmented by contracted trainers from AV. The Marine Corps instructors attended the Army's formal instructor training course at Ft. Benning, GA.

MCSC subsequently coordinated with Training and Education Command (TECOM) to develop a plan of instruction (POI) for the Marine Corps based upon the Army's Raven B formal course curriculum; however, the CG of TECOM approved the use of a contracted MTT as the long-term training solution for the Raven B system in 2008. Transition from the MCSC MTT to NAVAIR MTT occurred in conjunction with transfer of program responsibilities; however, the curriculum provides the same standardized training courseware throughout the Marine Corps.

The Raven MTT instruction involves classroom and practical application (field) training, which provides knowledge and understanding of system capabilities, limitations, and flight operations, to include all emergency procedures, navigation, airspace management, troubleshooting, and operator maintenance. The length of training is approximately 10 eight-hour days for new operators and five days for certified operators.

The Raven B system has a built-in simulator designed for use by operators to maintain their skills, which also helps reduce the total operating cost for the SURSS program. According to a logistics analyst at NAVAIR, one 10-day training session costs approximately $50,000.

b. Maintenance Training

The Raven program office scheduled classes for the Marines designated to perform I-level maintenance in 2008 to support CONUS fielding. AV conducted the classes at its facility in Simi Valley, CA, and covered advanced maintenance training; however, the 2008 fielding plan outlined that I-level maintenance training would shift to the responsibility of the MLG and should be included in their on-the-job-training (OJT) program in 2009. This training requirement for I-level maintenance personnel was eliminated with the 2011 CLS contract.

c. Training Analysis

NAVAIR and MCSC established a robust training system through formalized instruction in which competent Marines, soldiers, and contractors deliver quality operator training via MTTs. The primary benefit of MTTs is that they travel to the user and provide the using unit flexibility in scheduling periods of instruction based around a high, and sometimes unpredictable, operational tempo. They also save costs as they minimize the logistics associated with establishing a formal training environment with dedicated infrastructure such as manpower and facilities.

However, establishing the MTT method of training as a long-term solution has disadvantages as well. First, the using unit must schedule the training at a time that coincides with when the MTT is available. Secondly, the responsibility is upon the using unit to provide the logistics support, including space, for the MTT to unpack and inspect the unit's Raven B systems, a classroom for nine to 12 operators, a range safety officer, access to a training range, range training support, and airspace clearance. Without sufficient time and resources, these requirements could be a significant burden on a unit that does not have the flexibility or access to the necessary support.

Lastly, the lack of formal institutionalized training hinders the access to instruction for frequently rotating units and personnel. The MCCLL emphasizes the importance of more substantial training opportunities:

> the level of introductory training by the MTT provided minimal opportunities for operators to work with the system. The training period conducted at MV [Mojave Viper Exercise] also did not provide sufficient opportunities for the Marines to practice employing the system, according to the commanding officer. (MCCLL, 2009, p. 13)

The last disadvantage is part of the issue that likely contributed to the inexperience and insufficient knowledge that 1/4 and 2/23 Raven operators experienced in Iraq. Nearly all Marine units experience frequent deployments and a high rate of personnel turnover. The high personnel turnover issue directly impacts the unit’s requirement to screen qualified Marines prior to Raven operator training and extends into subsequent problems in maintaining and measuring operator proficiency, periodic recertification, and methods for conducting refresher training. Units that experience these issues face severe challenges in effectively scheduling training by MTTs, especially during a period shortly following new equipment fielding.

4. Materiel

Materiel broadly encompasses all the equipment and parts necessary to sustain military forces so they can operate effectively. In this section I analyze processes and capacities associated with supporting the Marine Corps Raven systems.

a. Fielded Systems

The approved acquisition objective (AAO) established for the Marine Raven system does not equal the number of maneuver companies in the entire Marine Corps. The three regular infantry divisions have more than 500 maneuver companies alone, and that number does not account for special operations units, expeditionary units, logistics units, air wing units, reserve forces, or the war reserve. Through the Raven fielding process, the MEF commander is responsible for establishing and managing fielding priorities within the MEF and controlling its established fielding schedule based on mission requirements and unit availability. The MEF commander must then decide

how many systems a subordinate command receives, and likewise the subordinate commander must decide which unit receives the Raven system. Based on an AAO of 461 systems, not every maneuver company will receive a Raven system.

b. Repairables and Consumables

In 2007 MCSC and MCLC coordinated with AV to review and disassemble the Raven to determine which parts made-up the O-level spares and I-level parts. AV provided all the necessary component information to MCLC, who loaded the data into the Marine Corps' automated supply and maintenance information management systems. MCLC also prepared logistics forecasts to estimate and purchase an initial allowance of parts based on AV's engineering specifications (i.e., mean time between failures, mean time to repair, etc.) and the Army's actual Raven usage data from previous years. MCLC placed parts needed to support the intermediate level of maintenance on contract with AV (MCSC, 2008c). According to a logistics analyst at MCLC, parts were sufficiently available in time for the planned CONUS fielding in 2008.

The MCLC provided supply support for Raven through contracts managed for secondary repairables (SECREPS) and DLA for Class IX consumable materials during the initial fielding and sustainment of the system. Additionally, the program office purchased and distributed the ISP with each system to every receiving major command for operator repairs as well as an initial-issue provisioning (IIP) package. The IIP contained SECREPS for the RIP and Class 9 consumable parts for the MLG general supply account (MCSC, 2008c).

The CLS contract in 2011 coordinated all subsequent supply support through AV who, as the OEM, provides the most responsive and comprehensive support for parts. The operator and using unit now use the FRA in Afghanistan and the AV CONUS facility to order repairable and consumable parts.

c. Information Management Systems

The Marine Corps mandates the use of a computer-based information management system to support commanders and logisticians at all levels to facilitate

supply and maintenance management and maintain visibility on the readiness statuses of its ground equipment. Marines use the Marine Corps Integrated Maintenance Management System Automated Information System (MIMMS/AIS) to input and reconcile data for requisitioning all repair parts and maintenance-related supplies in support of organic sustainment operations. Only Marines designated with supply- and maintenance-related specialties have access to the system; therefore, the typical Raven operator must rely on the support of external organizational or intermediate-level activities to replenish Class IX repairables and consumables.

d. Materiel Analysis

There is valid evidence that procedural shortfalls likely contributed to the excessive lead-time for requisitioned repair parts during the initial fielding period. However, the excessive turnaround time associated with the supply chain is not necessarily due to lack of material parts in the overall Marine Corps sustainment strategy.

Since the quantity of Ravens is limited and not every maneuver company receives a system, the commanders within each MEF divided and distributed the Raven system along with its three air vehicles to best share the capability with its subordinate units. The advantage to that practice is obvious on the surface; however, it has inherent disadvantages that likely caused some of the support issues 1/4 and 2/23 reported in 2008. The general concept of operations is to employ the Raven as a complete system, not as individual air vehicles. Upon fielding, only one FRK and one ISP accompany the system. However, because the system is divided among units that are sufficiently dispersed during combat, the spare parts are consumed rapidly or are otherwise difficult to attain before timely replenishment.

Another issue related to supply chain responsiveness is the time-limiting factors linked to the verification process for requisitioned supplies at the Marine Corps' D-level activities. There is an inherent administrative burden at MCLC and DLA commonly associated with fielding new systems. Although the parts and supplies may be available, the rate of turnaround is slow, as the overall logistics management system transitions from one major end item to another.

However, MCSC and NAVAIR planned for the slow build-up of supplies in the theater supply chain commonly associated with fielding new systems.

The largest contributor to the apparent lack of supply support are most likely (a) inexperience or lack of proficiency associated with the Raven operators' maintenance tasks combined with (b) the lack of knowledge regarding supply and maintenance activities. Fundamentally, an effective supply chain relies on many things, but chiefly upon its users proficiency and knowledge of its users on how the system works. The supply chain from the operator to the intermediate-level supply and maintenance activities was broken in 2008; it was not sufficiently defined for Raven operators and using units to implement the organizational-level tasks. This was the responsibility of the commanders and using units within MEF.

An apparent symptom of the supply chain problem became evident when I, in the course of this research, was unable to extract usable or accurate historical data from the Marine Corps' information management tool (MERIT) regarding the Raven. MERIT is a web-enabled suite of software applications that graphically depict the current readiness posture and detailed supply and maintenance information for all Marine Corps readiness reportable equipment. MERIT is a conduit of information that reflects the input into the MIMMS/AIS from supply and maintenance specialists throughout the entire Marine Corps. Neither the MCLC nor PMA-263 logistics analysts could verify with any confidence the accuracy or amount of factual data in the official Marine Corps information system. These observations are evidence that the supply and maintenance procedures clearly laid out in official instructions were not followed.

5. Leadership and Education

The leadership and education analysis examines how the Marine Corps prepares and develops leaders and then how those leaders lead. Leaders from the lowest to the highest levels in both Marine Corps and acquisition positions are the key to any program's success.

a. Military Operational Leadership

The key military leaders include a variety of positions that range in level of responsibility and management for the Raven. These military leaders are on the operating spectrum of the Marine Corps and have the most influence over the Raven's day-to-day use and direct sustainment. The leaders most closely related to the operation of the Raven include the company commanders and their key staff, whereas the MEF commanders are at furthest distance from the actual system.

b. Acquisition and Supporting Establishment Leadership

Key acquisition professionals and leaders in the supporting establishment also include a variety of positions that range in degree of responsibility and management for the Raven. These leaders have the most influence over the Raven's initial and long-term sustainment. The acquisition professionals and supporting establishment roles most closely related to the sustainment of the Raven are the program officers and their key staff of engineers and logisticians, especially at the onset of the program and its initial stages of fielding. Typically, after an initial transition period, a weapon system's sustainment shifts to the supporting establishment responsible for long-term sustainment.

c. Leadership Analysis

The commanders and logisticians throughout the operating forces as well as in the supporting establishment must have a thorough understanding and knowledge of the operations and sustainment processes for any pivotal intelligence system such as the Raven. The effective employment of operational commanders' warfighting capacities and the success of their operations depends not only upon the functional capability of the Raven system, but also its operational availability.

Part of this responsibility rests with the acquisition community and supporting establishment. They must provide the proper support mechanisms and education to the operating forces. The remainder of the responsibility rests with the operational commanders themselves and their logisticians. Without their ardent interest, authoritative influence, and directed guidance, a weapon system like the Raven could fail

to fulfill its full potential due to deteriorated support, as apparent from cited reports. The more leaders understand the value of the Raven and the more involved they become in its sustainment, the more effective the system would become. There should be incentive enough to provide the necessary energy for Raven support and direction to strengthen the sustainment process because a non-mission capable Raven does not aid the commander's battlefield awareness. Instead, it only serves to hinder the unit's capability in combat. Nonetheless, the 2011 transition from organic supply and maintenance to the heavily weighted CLS sustainment construct was generally the result of leadership failure.

6. Personnel

In this personnel analysis I examine the availability of qualified people to sustain forces during peacetime, wartime, and contingency operations. I explore the various requirements associated with sustaining the Marine Corps Raven by looking at two operationally critical roles, the operator and the maintainer.

a. Operator

Unlike the larger UASs in Groups 2 and 3, the CONOPS for the Raven involved no authorized changes to personnel requirements or tables of organization for using units. The 2008 and 2011 fielding plans stated that any military occupational specialty (MOS) with minimal appropriate training could operate the Raven. Aligned with the concepts established by early capability requirements documents, the Raven operator is a collateral duty assigned to personnel from within the using unit's organization.

Thus, conducting Raven operations was not intended as a primary duty or occupational specialty. As such, the fielding documents advise commanders to anticipate the effect Raven operations would have on their Marines' primary duty. The simple, yet not formally definitive, screening of potential operators by unit commanders includes no extraordinary physical requirements besides being able to carry and launch the system, the ability to read maps and conduct land navigation, and having a minimal working knowledge of computers.

b. Maintainer

For the initial organic sustainment strategy, the 2008 fielding plan stated that Marines in ground electronics maintenance occupational field (OccFld) 28XX would perform the I-level maintenance. The 28XX OccFld tasks incorporate various maintenance activities for common communications equipment used by Marine Corps ground forces, to include support for the Raven such as diagnosis, repair, adjustment, and modification of electronic equipment typically found on UASs. These Marines conducted I-level maintenance on the Raven system as a concurrent duty similar to what they had done for the Dragon Eye systems. With the 2011 CLS contract, the requirement for these Marines to perform I-level maintenance dissolved with the elimination of the organic intermediate sustainment construct.

c. Personnel Analysis

One of the primary advantages of not assigning a primary MOS or primary duty as a Raven operator is flexibility of employing the Raven at any level of the MEF without requiring specially trained Marines. However, a disadvantage is tied to the discussion in Part 3 of this section regarding training in an operational environment with a high rate of personnel turnover. Often the few certified Raven operators in a unit inevitably transfer at random times and leave the unit with a capability gap.

Moreover, without the assignment of an MOS, the Marine Corps has no automated method of filtering Raven-qualified Marines in order to make manpower assignments based on capability needs. Although commanders attempt to plan for this and schedule MTT instruction to mitigate those risks, many logistical and operational factors already mentioned may prevent the formal training from happening and then default to OJT. This latter method of training creates significant shortfalls in operator skills, which undoubtedly led to some of the organizational sustainment problems previously discussed throughout this section.

General John Joseph “Black Jack” Pershing—Commander of the American Expeditionary Forces during WWI—was famously quoted as once saying, “The deadliest weapon in the world is a Marine and his rifle!” In other words, one of the

most effective weapons systems of that time was an infantry Marine and his Springfield rifle. An infantry Marine is indelibly linked to his assigned weapon, which has capabilities with which he is more than thoroughly familiar and proficient. But he is also an expert on how to maintain it in the field and knowledgeable of where to get support beyond his own capability. The same holds true of a Marine motor vehicle operator and his tactical truck or a communications Marine and his field radio. The infantry Marine knows how to get support from the armory, the vehicle operator from the motor pool, and the radio operator from the staff communications sections. However, the same does not hold true of an infantry or intelligence Marine and the Raven to which he was only relatively recently assigned as a collateral duty.

7. Facilities

In the following analysis of facilities I explore the potential that military property, government-owned installations, or industrial facilities that support military forces might serve as a method of filling a sustainment capability gap.

U.S. Code, Title 10, Section 2464 requires that the DoD maintain a government-owned and -operated core logistics capability to ensure its forces are rapidly and effectively sustained in case of emergency or contingency operations. Typically, military D-level repair and supply facilities satisfy this requirement; however, with an increased emphasis on procuring commercial equipment, the DoD has progressively relied on commercial contracts to fill its non-organic sustainment gaps. The Army's 2007 CDA report "determined that the [Army's] current organic industrial base does have the technical capability and capacity to provide depot-level maintenance support for all SUAS Pathfinder Raven hardware" (PEO AVN, 2007b, p. 2). Furthermore, the report includes recommendations to consider the Raven as non-core system and for PM-UAS to conduct a BVA on three alternatives for long-term sustainment.

The three alternatives under consideration in the 2007 BVA were (1) a 100% organic supported depot, (2) a 100% contractor supported depot, and (3) a mixture of both organic and contractor (PEO AVN, 2007a). The conclusion of the report highlighted the Army's organic depot's capability gap regarding the lack of requisite test

and calibration equipment, technical data, and procedures, all of which were exclusively resident with AV. The final recommendation was that the Army should maintain the contract relationship with AV for depot-level support based on two significant factors. First, the cost to purchase the technical data from AV was prohibitive at over $40 million (not including the cost of test and calibration equipment). Second, the risk associated with technological obsolescence and frequency of updates for systems was too high. PMA-263 concurred with the findings in the BVA and furthermore used it as partial basis for initiating the modified CLS contract in 2011 for intermediate support.

C. COST ANALYSIS

a. Affordability

When PMA-263 procured the Raven B during its phase following Milestone C, the program had full funding to meet the Marine Corps' AAO. It avoided costs that the Army had absorbed for the transition of the Raven from its system development and demonstration phase. The acquisition plan stated, "based on the cost comparison of the Life-Cycle Cost Estimates (LCCEs) for Block 0 and Block 1, the program will see a reduction in cost based on Then Year (TH) projections of $86.1M over the life (20 years) of the program" (MCSC, 2008a, p. 30). The decision to transition from the Dragon Eye to the Raven saved the Marine Corps significant budget room. After the program was re-baselined to reflect the new LCCE, PMA-263 was able to properly resource the procurement of the approved quantity of both systems and support to equipment outlined in the 2006 O&O (MCSC, 2008a).

b. Total Ownership Cost (TOC)

The TOC reduction of $86.1 million realized from the transition to the Marine Raven B was a result of survivability and reliability improvements the Army PM-UAS had made based upon lessons learned from the Raven A. Moreover, the Marine Corps benefited from the overall reduction of O&M costs based on the system's improved reliability and increased survivability. Additionally, PMA-263 saved $8.4 million in research and development (R&D) funding originally planned for capabilities improvements for the Dragon Eye. Lastly, the Marine Corps benefited from the joint

procurement of the Raven system, resulting in about $14,000 in savings per system over the Dragon Eye in addition to savings in spare parts (MCSC, 2008a).

c. Cost Comparison of Modified CLS

Using the costs for logistics support elements identified in the logistics requirement and funding summary (LRFS) found in the 2008 supportability plan, I extrapolated the average cost to support the Raven B for one year under the initial sustainment plan with organic I-level support (MCSC, 2008b). The calculated yearly cost of organic support inferred from the LRFS is approximately $9 million after adjusting the price to account for today's value using a 7% inflation rate over four years. Additionally, using the costs derived from the six-month modified CLS contract let in 2011, I adjusted those figures to reflect minor additional logistics elements that I estimated the Marine Corps would assume and calculated the cost over a one-year period. The estimated cost of the modified CLS contract is approximately $16 million in today's dollars. The difference between the previous organic sustainment arrangement and the new contracted support is an expense of about $7 million per year or about $140 million total lifetime cost in present value over 20 years.

d. Comparison of Benefits and Limitations

Using the primary alternatives of either organic support or CLS, Table 4 and 5 illustrate the comparison of advantages and disadvantages.

Table 4. Advantages and Disadvantages of Organic Support (After: PEO AVN, 2007a)

Organic Analysis	
Advantages	Disadvantages
Meets Title 10 requirement	Need to establish organic capacity at various locations
Centralized Distribution Management (MCLC&DLA)/Decentralized Execution (IMA&RIP)	Increased personnel requirements
Lower cost for support personnel	Higher risk to Government (assuming full responsibility for configuration management)
	Difficult to incentivize
	Higher cost due to proprietary data requirements

Table 5. Advantages and Disadvantages of CLS (After: PEO AVN, 2007a)

Contractor Logistics Support (CLS) Analysis	
Advantages	Disadvantages
Immediate source of skilled personnel	Title 10 not immediately met
Immediate availability of peculiar spares	Delay in organic transition
Lower risk to Government (AV maintains configuration management after IOC)	Cost Plus contracts associated with out years

V. CONCLUSIONS AND RECOMMENDATIONS

This study serves as a compilation of information and valuable lessons learned through a reflection of the Marine Corps' historical relationship with unmanned aerial systems and a detailed analysis of its more recent acquisition and sustainment efforts that support the RQ-11B Raven. The goal of the research was to explore and analyze the operational impacts of the Raven support plan directly affecting the warfighter in order to

- document the Marine Corps Raven SUAS sustainment process and organization;
- research and record lessons learned;
- assess the performance for the sustainment of the past and current programs;
- determine what benefits the Marine Corps realized through the current OEM-CLS contract; and
- develop heuristics and/or criteria to help improve Marine Corps UAS acquisition and sustainment processes.

A. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

1. Research Questions

a. Operational and Logistics Impacts

What are the operational and logistical impacts of using a hybrid organic/CLS solution for supply and maintenance support of the RQ-11B Raven?

(1) Findings. I analyzed the full spectrum of both operational and logistical impacts of the organic/CLS solution through the lens of the DOTMLPF framework, in which operating units felt the most notable negative effects when the Raven was more heavily supported through the organic means. Generally, this is not surprising considering that commercial industries such as AV are better equipped, funded, and skilled at supporting highly specialized pieces of equipment.

(2) Conclusions. Although the Raven seems like a quick COTS solution akin to a radio-controlled model airplane, it is not. It requires complex

systems of processes and supporting elements to adapt the system to military needs. The requirements range from simple operating procedures that fall under the doctrine portion of the DOTMLPF to more complex supply and maintenance procedures that fall under any number and combination of the DOTMLPF framework.

(3) Recommendations. With the detailed analysis covered in Chapter 4, I provide the foundation of the following recommendations:

- Doctrine: The Marine Corps should update or develop a more comprehensive warfighting publication incorporating current operating procedures beyond the limited scope of the VMU and UASs in Groups 2 and 3.
- Organization: The Marine Corps or MEF should provide delineating guidance to using units on a standard organizational construct for employing the Raven below the MEF level as well as clearly outline the level of repair a system requires while using an organic sustainment concept. I recommend the unit S-6 Communications section be the single source responsible for the maintenance and supply processes supporting the Raven because no other activity in an unit organization is as capable or more apt to facilitate the repair and supply flow.
- Training: The Marine Corps should establish a memorandum with the Army Infantry School at Ft. Benning to allow Marine operators to attend their formal basic instruction (such as with instructors at the master trainer course) in order to add flexibility of scheduling classes for individual Marines when needed. Alternately, the Marine Corps should conduct a feasibility study on establishing a formal course through its own organic school establishments (e.g., Advance Infantry Training Battalion, etc.).
- Materiel: The Marine Corps should either approve a higher number of Raven systems for procurement and fielding, or purchase additional components to outfit more FRKs, ISPs, and RVTs to accommodate how units are dividing the system into its three air vehicles.
- Leadership: Leaders (i.e., commanders, logisticians, etc.) should receive some formalized instruction educating them on the Raven's capabilities and limitations, including factors affecting sustainment (e.g., Infantry Officer's Course).
- Personnel: At a minimum, Raven operators should be designated with a secondary MOS once certified on the system in order for units and the Marine Corps to better manage the turnover of personnel and mitigate risks for capability gaps. I recommend the

using unit S-6 maintenance section be augmented with either an electronics maintenance technician or training to facilitate proper troubleshooting and repair at the organizational level.

b. Costs of the CLS Contract

Is the cost of the modified CLS contract supporting the RQ-11B Raven worth the supply and maintenance benefits?

(1) Conclusion. Mitigating support deficiencies to ensure the Raven remains operational for Marines in combat is worth the cost of a CLS contract. However, I cannot determine if the additional $7 million per year, or $140 million over the lifetime of the Raven, is worth the advantages the CLS provides to the Marine Corps. Typically, when the military purchases a new system, the default sustainment strategy initially involves an interim CLS construct. Although it is the more expensive, it provides the sufficient time to establish an organic capability, which could take a year or more. Instead, MCSC initiated the opposite support strategy, choosing to use organic support first. After PMA-263 realized the lack of sufficient support to the warfighter, Marine leadership made the decision to revert to a similar CLS strategy the Army used since it initially procured the Raven in 2003.

While there are fewer advantages to using organic resources over CLS, the tendency for decision-makers today is to select the cheapest solution because it has the most immediate monetary cost savings. This is likely a reflection of tightened budgets and restricted resources in more recent years and the drawdown of contingency operations overseas. However, there is typically a tradeoff when this happens: organic support is much harder for the military to manage and is much less responsive to customer demand—especially when fielding new equipment.

Furthermore, the establishment of an enduring supply and maintenance chain has become more difficult in the advent of more technologically advanced systems that frequently require updates and modifications. The bottom line is the cheapest support is almost never the best support; leaders need to understand how to balance the cost and performance of a system's sustainment strategy and decide on the best value.

(2) Recommendations. The Marine Corps should continue to use the CLS contract to support the Raven DDLs negotiated by PMA-263 until such a time that the program office determines that there is a better value alternative. The recommendation for future acquisition and sustainment strategies should follow the traditional CLS construct to support newly-fielded systems. After a period of time when the organic supply and maintenance activities determine they are operationally capable to effective support the Raven, then CLS should transition to organic support through close coordination among the various organizations. However, leaders and logisticians at all levels need to pay strict attention to the performance of their sustaining activities and supply chain, adopt a genuine interest, and assume responsibility for the success or failure of their activities. The organic sustainment strategy could have been successful at the O-level and I-level support activities if Marine Corps leadership at every echelon maintained and enforced the highest standards of performance from those organizations.

B. FUTURE RESEARCH OPPORTUNITIES

There are numerous emerging opportunities to conduct research for the Marine Corps that would benefit the future acquisition efforts for unmanned systems. The following recommendations are only a few that closely relate to this project:

- What Group 1 UAS capabilities are most needed by future tactical units?
- What is the most advantageous mix of unmanned aircraft types offers the most flexibility to the Marine Corps tactical unit?
- What are the sustainment organizations and processes for other Marine Corps UASs used at Groups 2 and 3?

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